# GEOPHYSICAL SURVEYS FOR ASSISTING IN DETERMINING THE GROUND WATER RESOURCES NORTH KOHALA SITE ISLAND OF HAWAII

Blackhawk Geometrics Project Number 9831CIH

*Prepared For:*

**CHALON INTERNATIONAL OF HAWAII, INC**

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Blackhawk Geometrics Project Number 9831CIH

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# 1.0 INTRODUCTION

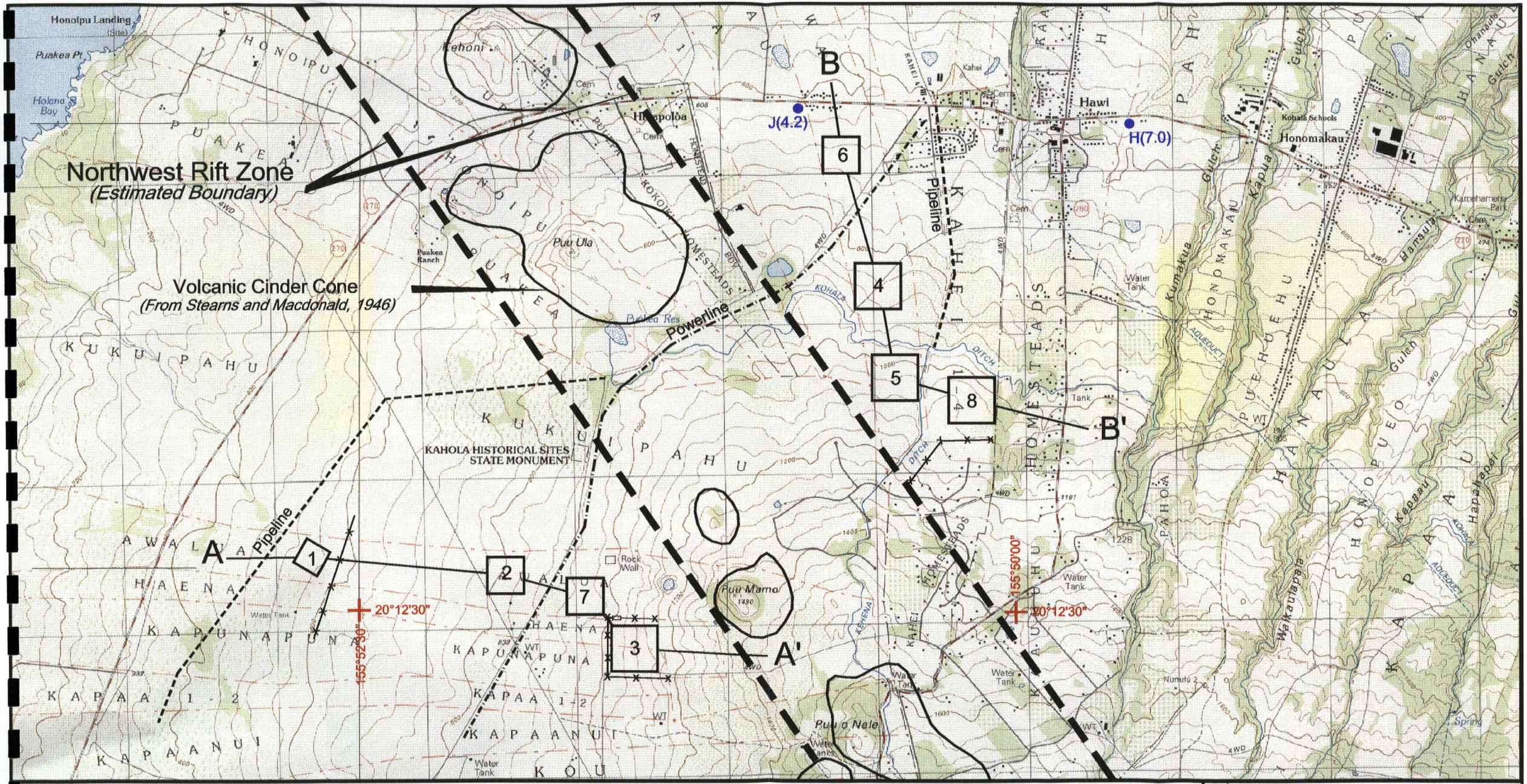
This report contains the results of geophysical surveys conducted to assist in determining the ground water resources in the North Kohala area near the town of Hawi, Hawaii. The surveys were performed by Blackhawk Geometrics (Blackhawk) for Chalon International of Hawaii, Inc. (Chalon) during September 29 to October 10, 1998. The geophysical method employed during this survey was Time Domain Electromagnetic (TDEM) soundings. The TDEM soundings were positioned southwest of the town of Hawi as shown in Figure 1-1. The Kohala area of the island of Hawaii is the northwest peninsula of the island. This portion of the island is dominated by the elongated Kohala Mountain and the associated Northwest Rift Zone (Stearns and Macdonald, 1946). The Kohala Mountain is the oldest of the five volcanoes forming the island and reaches an altitude of 5,605 feet.

The main objective of the geophysical survey was to assist in characterizing the hydrologic regime in the North Kohala study area for a proposed ground water well. Ground water resources can occur on the Island of Hawaii basically in two modes:

- In a basal mode, where a lens-shaped body of fresh water floats on saline water, and
- In a high-level mode, where the ground water occurrence is controlled by subsurface damming structures.

These two types of ground water occurrences are illustrated in Figure 1-2. The surficial volcanic rocks are generally highly permeable and this allows rainwater to infiltrate directly downward through the island mass. In the Hawi area, ground water was expected to occur as both a deep basal fresh-brackish water lens and possible high-level water occurrences at locations above subsurface damming structures (i.e., dikes, rift zones).

Previous TDEM surveys on the Hawaiian Islands have reliably mapped the boundary between fresh water in the basal mode and high-level water occurrences. Geophysical surveys, combined with other hydrogeologic information, are used to provide optimum locations for well placement and completion depths.




## Explanation

- 1 — TDEM Soundings
- A-A' — Section Line
- H(7.0) — Well, Water Level (In Feet)

Hawaii

Survey Location

0 2000 4000 6000

Scale in Feet

Contour Interval 40 Feet

True North 10° Magnetic North

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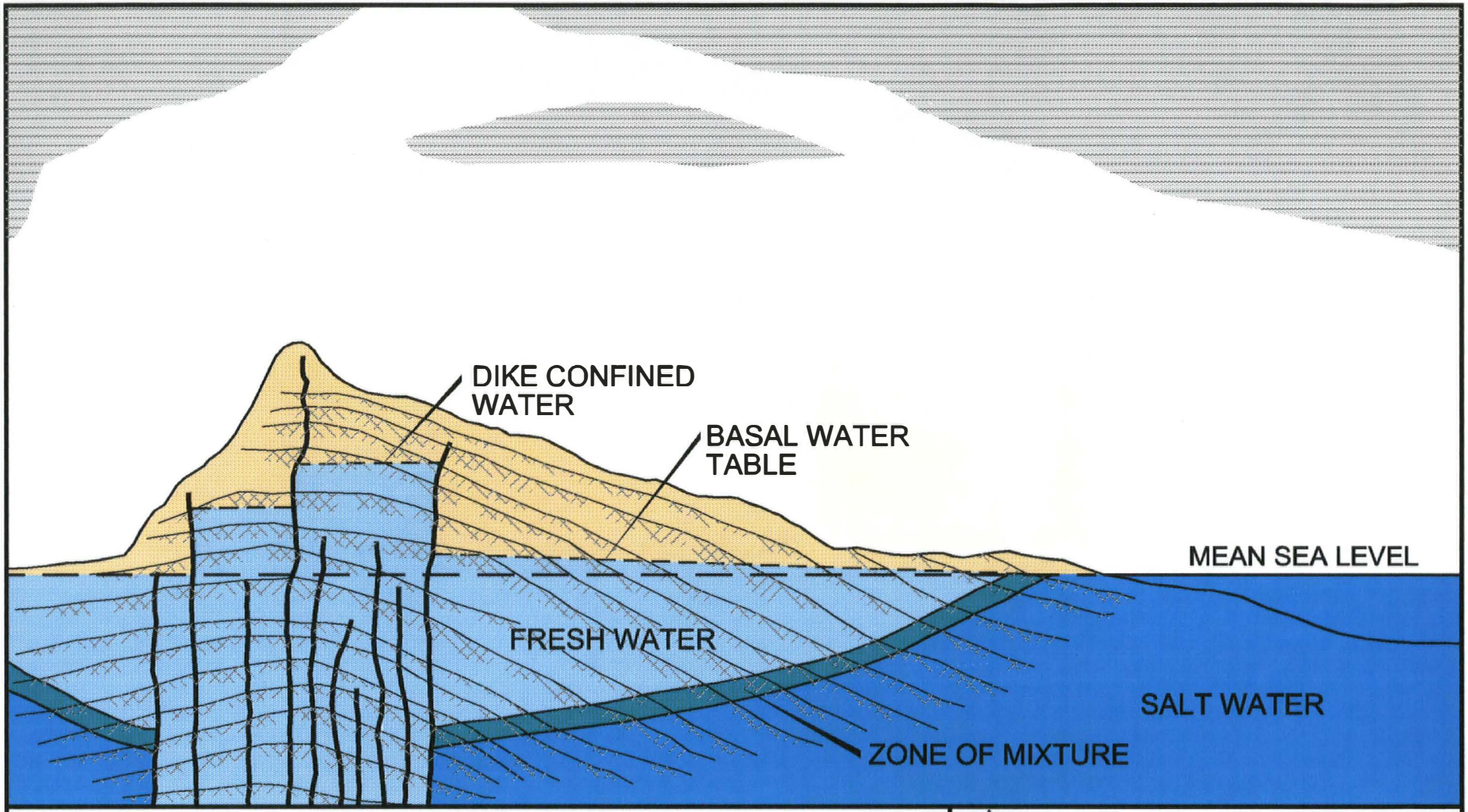
# Location Map
# North Kohala Site

*Chalon International of Hawaii, Inc.*
*Hawi, Hawaii*

Project No. 9831 Figure: 1-1

\projects\9831cih\Locmap.dwg

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# Schematic Hydrogeologic Cross Section

*Chalon International of Hawaii, Inc.*
*Hawi, Hawaii*

Project No. 9831 Figure: 1-2

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## 2.0 DATA ACQUISITION AND LOGISTICS

The geophysical equipment used for the Time Domain Electromagnetic (TDEM) surveys was the Geonics EM37 System. The EM37 system consists of both a portable transmitter and receiver. TDEM measurements were acquired using a central-loop sounding array at each site. With this array, measurements are recorded with a receiver at the center of transmitter loops laid on the ground surface. For data quality control comparisons, several offset measurements are also made at designated locations near the center of each loop. The transmitter loops are constructed with 12-gauge insulated copper wire. The dimensions of the square loops at the North Kohala site varied from 600 ft by 600 ft to 1000 ft by 1000 ft. A 2.8 kW transmitter was placed in each sounding loop to drive current ranging between 14.5 and 17.5 amperes at base frequencies of 3 Hz and 30 Hz. At the center of each transmitter loop, the time derivative of the vertical magnetic field was recorded with a receiver coil with an effective area of 100 $m^2$. The data acquired at each sounding consisted of measurements at several receiver gain settings and two transmitter frequencies in order to assure data quality and to obtain data over the largest time interval possible. Data quality was excellent, due to efforts made in the field in positioning the soundings away from potential cultural noise sources (i.e., pipelines, powerlines). The data from each sounding was stored in the field on an Omnidata polycorder and, subsequently, transferred to a PC for nightly processing. A brief technical note describing the principles of TDEM is given in Appendix A.

A total of eight soundings was completed over the survey site. A daily log of field activity is given in Table 2-1. Sounding loop locations were measured by compass and hip-chain from known landmarks (i.e., roads, ditches). The elevation of each sounding center was measured using an Avocet Vertech Altimeter/Barometer. The altimeter was adjusted during the course of a day at known landmarks (i.e., road junctions) with altitudes taken from a 7.5 minute series topographic map of the Hawi area. The field loop locations were selected by representatives of Chalon and Blackhawk Geometrics. The locations were based on property ownership, available open land, and exploration objectives.

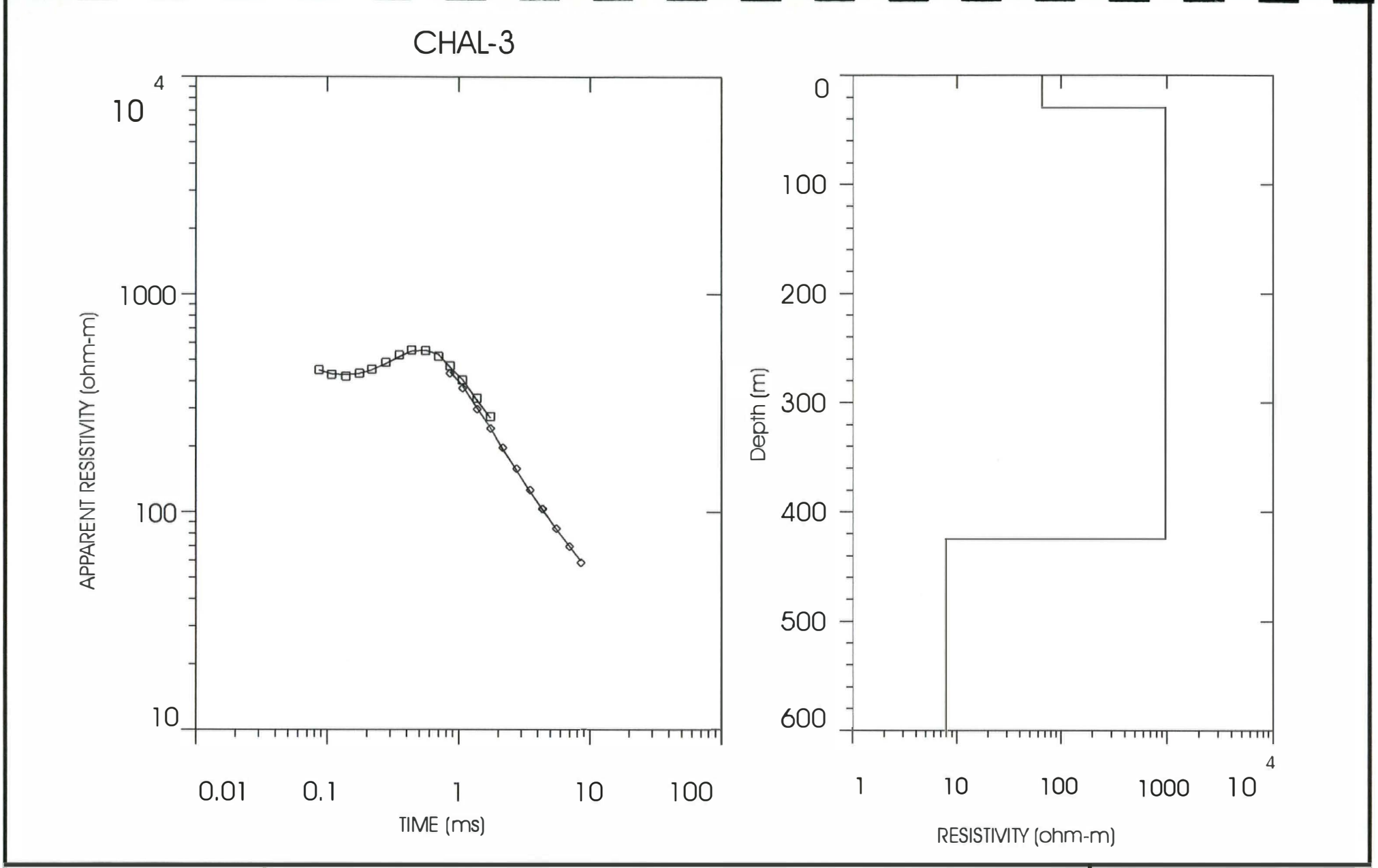
| TABLE 2-1<br>DAILY LOG OF FIELD ACTIVITIES | |
|---|---|
| **DATE, 1998** | **ACTIVITY** |
| September 23 | Mobilize geophysical equipment from Golden, CO, to Kona, HI. |
| September 28 | Mobilize Blackhawk Geometrics personnel from Golden, CO, to Kona, HI. Retrieve geophysical equipment from air cargo and organize into field vehicles. |
| September 29 | Meet with Chalon representative and their consulting hydrologist to discuss North Kohala project. Recon field site and begin TDEM survey with data acquisition on Sounding 1, south side of rift zone. |
| September 30 | Take data on Soundings 2 and 3, south side of rift zone. |
| October 1 | Acquire data on Soundings 4 and 5, north side of rift zone. |
| October 2 | Data taken on Soundings 6 and 7, both sides of rift zone. |
| October 3-9 | TDEM data taken on other Hawaii projects. |
| October 10 | Acquire data on Sounding 8, north side of rift zone. |
| October 11 | Demobilize geophysical equipment from Kona, Hi, to Golden, CO. |
| October 12 | Demobilize Blackhawk Geometrics personnel from Kona, Hi, to Golden, CO. |

# 3.0 DATA PROCESSING

The TDEM field data acquired each day was transferred from the Omnidata polycorder to a PC. The first step in processing the TDEM data is to average the electromotive forces (emfs) recorded at positive and negative receiver polarities. Next, the recordings made at different amplifier gains and frequencies were combined to give one transient decay curve with the program TEMIXXL (Interpex LTD). With this program, voltages measured with the 20 channels of the Geonics EM37 receiver are transformed into apparent resistivity verses time gate. The apparent resistivity curve is interpreted by inversion to a one dimensional (1-D) geoelectric section that matches the observed decay curve.

The inversion program requires an initial estimate of the geoelectric section, including the number of layers and the thicknesses and resistivities of each of the layers. The program then adjusts these parameters so that the model curve converges to best fit the curve formed by the field data. The inversion program does not change the number of layers within the model, but allows all other parameters to change freely, or they can optionally be fixed constant. To determine the influence and best fit of the number of layers on the solution, separate inversions with different numbers of layers are run. Normally, the model with the fewest number of layers which best fits the data is used.

An example of the output of the inversion program (Sounding Chal-3) is shown on Figures 3-1 and 3-2. Figure 3-1 shows the measured data points (in terms of apparent resistivity) superimposed on a solid line. The solid line represents the computed forward model of the geoelectric section shown on the right. Tabulated inversion parameters and results consisting of measured field data, computed data for best match solution, and inversion errors are given on Figure 3-2. The apparent resistivity curves and data sheets for all of the TDEM soundings are given in Appendix B.

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# TDEM Inversion Results
## Sounding CHAL-3
*Chalon International of Hawaii, Inc.*
*Hawi, Hawaii*

Figure: 3-1

Project No. 9831

\projects\9831cih\Results1.cdr

DATA SET: CHAL-3

CLIENT: CHALON INTERNATIONAL DATE: 09-30-98
LOCATION: HAWI, HAWAII SOUNDING: 3
COUNTY: NORTH KOHALA ELEVATION: 329.00 m
PROJECT: NORTH KOHALA TDEM SURVEY EQUIPMENT: Geonics PROTEM
LOOP SIZE: 305.000 m by 305.000 m AZIMUTH:
COIL LOC: 0.000 m (X), 0.000 m (Y) TIME CONSTANT: NONE
SOUNDING COORDINATES: E: 3.0000 N: 1.0000 SLOPE: NONE

Central Loop Configuration
Geonics PROTEM System

FITTING ERROR: 2.122 PERCENT

| L # | RESISTIVITY (ohm-m) | THICKNESS (meters) | ELEVATION (meters) | CONDUCTANCE (Siemens) |
|---|---|---|---|---|
| | | | 329.0 | |
| 1 | 65.37 | 29.27 | 299.7 | 0.447 |
| 2 | 972.0 | 395.2 | -95.48 | 0.406 |
| 3 | 7.78 | | | |

ALL PARAMETERS ARE FREE

CURRENT: 15.00 AMPS EM-37 COIL AREA: 100.00 sq m.
FREQUENCY: 30.00 Hz GAIN: 4 RAMP TIME: 160.00 muSEC

| No. | TIME (ms) | emf (nV/m sqrd) DATA | emf (nV/m sqrd) SYNTHETIC | DIFFERENCE (percent) |
|---|---|---|---|---|
| 1 | 0.0867 | 33235.8 | 33222.1 | 0.0412 |
| 2 | 0.108 | 20629.7 | 20387.4 | 1.17 |
| 3 | 0.138 | 11475.7 | 11224.5 | 2.18 |
| 4 | 0.175 | 6064.6 | 6060.6 | 0.0653 |
| 5 | 0.218 | 3281.5 | 3300.0 | -0.565 |
| 6 | 0.278 | 1603.8 | 1636.5 | -2.03 |
| 7 | 0.351 | 795.3 | 817.0 | -2.72 |
| 8 | 0.438 | 423.1 | 428.7 | -1.32 |
| 9 | 0.558 | 233.0 | 230.4 | 1.10 |
| 10 | 0.702 | 143.3 | 138.1 | 3.59 |
| 11 | 0.858 | 100.8 | 102.7 | -1.81 |
| 12 | 1.06 | 73.59 | 72.86 | 0.991 |
| 13 | 1.37 | 52.33 | 53.74 | -2.69 |
| 14 | 1.74 | 38.50 | 39.29 | -2.04 |
| 15 | 0.857 | 113.7 | 110.4 | 2.95 |
| 16 | 1.06 | 83.37 | 80.13 | 3.88 |
| 17 | 1.37 | 62.32 | 60.69 | 2.62 |
| 18 | 1.74 | 46.28 | 45.88 | 0.855 |
| 19 | 2.17 | 36.23 | 37.30 | -2.93 |
| 20 | 2.77 | 27.39 | 28.08 | -2.51 |
| 21 | 3.50 | 21.49 | 21.96 | -2.20 |
| 22 | 4.37 | 16.61 | 16.75 | -0.825 |
| 23 | 5.56 | 12.42 | 12.52 | -0.852 |
| 24 | 6.98 | 9.34 | 9.31 | 0.338 |
| 25 | 8.56 | 7.26 | 7.06 | 2.63 |

PARAMETER RESOLUTION MATRIX:
"F" INDICATES FIXED PARAMETER

| | P 1 | P 2 | P 3 | T 1 | T 2 |
|---|---|---|---|---|---|
| P 1 | 0.95 | | | | |
| P 2 | 0.05 | 0.41 | | | |
| P 3 | 0.01 | -0.12 | 0.76 | | |
| T 1 | -0.04 | -0.08 | -0.01 | 0.94 | |
| T 2 | 0.00 | 0.02 | 0.00 | 0.01 | 1.00 |

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# TDEM Inversion Results
# Sounding CHAL-3
*Chalon International of Hawaii, Inc.*
*Hawi, Hawaii*

Figure: 3-2

Project No. 9831

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# 4.0 INTERPRETATION RESULTS

## 4.1 General

The main objective of TDEM soundings is to derive the resistivity layering (geoelectric section) of the subsurface. The translation of resistivity layering into hydrologic information is generally accomplished by two methods. These include:

1) Using available knowledge about the relation between resistivity values and local hydrology. From more than 25 previous TDEM surveys on the Hawaiian Islands, it has been observed that volcanic rocks saturated with salt water exhibit resistivities typically less than 5 ohm-m. Conversely, volcanic rocks that are dry and unweathered, or fresh water saturated, exhibit high resistivities (generally greater than 500 ohm-m). Weathered volcanics or ash flows and intrusives often exhibit intermediate resistivities (about 10 ohm-m to 100 ohm-m).

   Applying this information, characteristic ranges of resistivities expected for local hydrogeologic units for the North Kohala area are shown in Figure 4-1. It should be noted that some overlap in resistivity values occur. In these cases, other factors are used to infer the geologic/hydrologic unit in question. For example, a low resistivity unit (i.e., less than 10 ohm-m) occurring at an elevation above sea level is assumed to be caused by either weathered rock units or intrusives (i.e., dikes) instead of salt water saturated formations.

2) Another method is to calibrate the geophysical interpretation at a well. There was well information available in the Hawi area, but it was determined by Chalon that a comparison to the TDEM data was not needed for this study.

Where a very conductive layer (less than 5 ohm-m) is detected below sea level in the TDEM measurement, the layer is interpreted to be caused by salt water saturated volcanics. Static fresh water levels can be calculated from these soundings by using the Ghyben-Herzberg relation as illustrated in Figure 4.2. The Ghyben-Herzberg relation states that for every 1 ft of fresh water above sea level, approximately 40 ft of fresh water will exist below sea level. However, hydrostatic equilibrium is assumed for these measurements, and this relation is not expected to apply to soundings in close proximity to major geologic structures (i.e., rift zones, dikes) which act to alter ground water flow. Rift Zones can contain vertical dikes and faults, which run parallel and subparallel to the main rift orientation for hundreds of feet on either side of the central rift corridor. Intersecting dikes are common in rift zones and ground water can become compartmentalized between the dikes. Rift zones may also contain a series of volcanic cinder cones, which trend linearly away from a central caldera or volcanic dome.

## 4.2 Geoelectric Cross Sections

The results of the inversion of the individual TDEM soundings is the1-D resistivity layering as a function of depth. The TDEM results from individual soundings can be linked together to produce a 2-D geoelectric cross section along a survey transect. The geoelectric cross section can be correlated to geologic units by comparison with available geologic information. Two geoelectric cross sections were constructed from the North Kohala data. The directions of the geoelectric cross sections are shown on Figure 1-1.

## Cross Section A-A'

Figure 4-3 shows the results of four TDEM soundings presented as a West to East trending geoelectric cross section (A-A'), in which layers that exhibit similar resistivity values have been linked together.

The upper layer (green) of the geoelectric cross section beneath Soundings 2,3, and 7, displays resistivities ranging from 65 ohm-m to 69 ohm-m. This upper layer is interpreted to represent weathered surficial volcanics, which range in thickness of 90 ft beneath Sounding 2, to 130 ft beneath Sounding 7. The middle layer, with resistivities ranging from 110 ohm-m to 972 ohm-m, is interpreted to represent unweathered volcanics above sea level and where it occurs below sea level, it is expected to be saturated with fresh-brackish basal water. The lower layer (blue) beneath Soundings 1, 2, and 7 exhibits a resistivity of 2.5 ohm-m and is interpreted to represent salt water saturated volcanics. The thickness of the fresh-brackish water lens can be estimated beneath these three soundings, and it is interpreted to be thickest beneath Sounding 7 at 182 ft.

Sounding 3 is located 2,500 ft west of Puu Mamo, which is near the west boundary of the Northwest Rift Zone. Beneath Sounding 3, a low resistivity value of 7.8 ohm-m is interpreted to occur below sea level (green). This resistivity value is expected to be influenced by lateral discontinuities (i.e., dike, rift zone). Because of rapid lateral variations in resistivities between Soundings 3 and 7, the interpreted resistivity stratification may not represent true formation resistivity for Sounding 3. The exact position and width of the discontinuity is uncertain due to TDEM data density. Since a salt water interface was not interpreted beneath Sounding 3, the elevation of the ground water table cannot be calculated by the Ghyben-Herzberg relation. However, because the top of the low resistivity layer (7.8 ohm-m) is interpreted to be 313 ft below sea level, the potential for fresh water occurring beneath Sounding 3 is good.

## Cross Section B-B'

The geoelectric cross section results for B-B' are shown in Figure 4-4. The surface layer (green) of the cross section exhibits resistivities ranging from 62 ohm-m to 92 ohm-m. This upper layer is interpreted to be weathered surface volcanics, which vary in thickness from 150 ft beneath Sounding 4 to 280 ft beneath Sounding 6. The second layer in the section, exhibits resistivities from about 846 ohm-m to 1864 ohm-m. This second layer is interpreted to represent unweathered volcanics above sea level, and where it occurs below sea level, it is expected to be saturated with fresh-brackish basal water. The lower layer (blue) beneath Soundings 6 and 8 with resistivity of 2.5 ohm-m, is interpreted to represent salt water saturated volcanics. The thickness of the fresh-brackish water lens is estimated to be 210 ft beneath Sounding 6, and 431 ft beneath Sounding 8.

Soundings 4 and 5 are interpreted to be located in a complex area where a low resistivity value (7.6 ohm-m to 8.4 ohm-m) is measured 372 ft and 739 ft below sea level, respectively, and a lateral discontinuity (i.e., dikes, rift zone) is interpreted. The salt water interface was not interpreted beneath Soundings 4 and 5, and therefore, the elevation of the water table cannot be estimated by the Ghyben-Herzberg relation. Since the boundary of the low resistivity layer is interpreted below sea level, the possibility of fresh water occurrence beneath Soundings 4 and 5 appears to be good.

## 4.3 Hydrogeologic Interpretation

In five of the eight TDEM soundings from the North Kohala Site, salt water saturated volcanics were detected below sea level. The fresh-brackish water resource can be estimated in these soundings by the volume between sea level and the interpreted elevation of salt water interface, plus the head calculated from the Ghyben-Herzberg relation. Table 4-1 shows the thickness of the fresh-brackish water lens interpreted directly from the model results for each sounding.

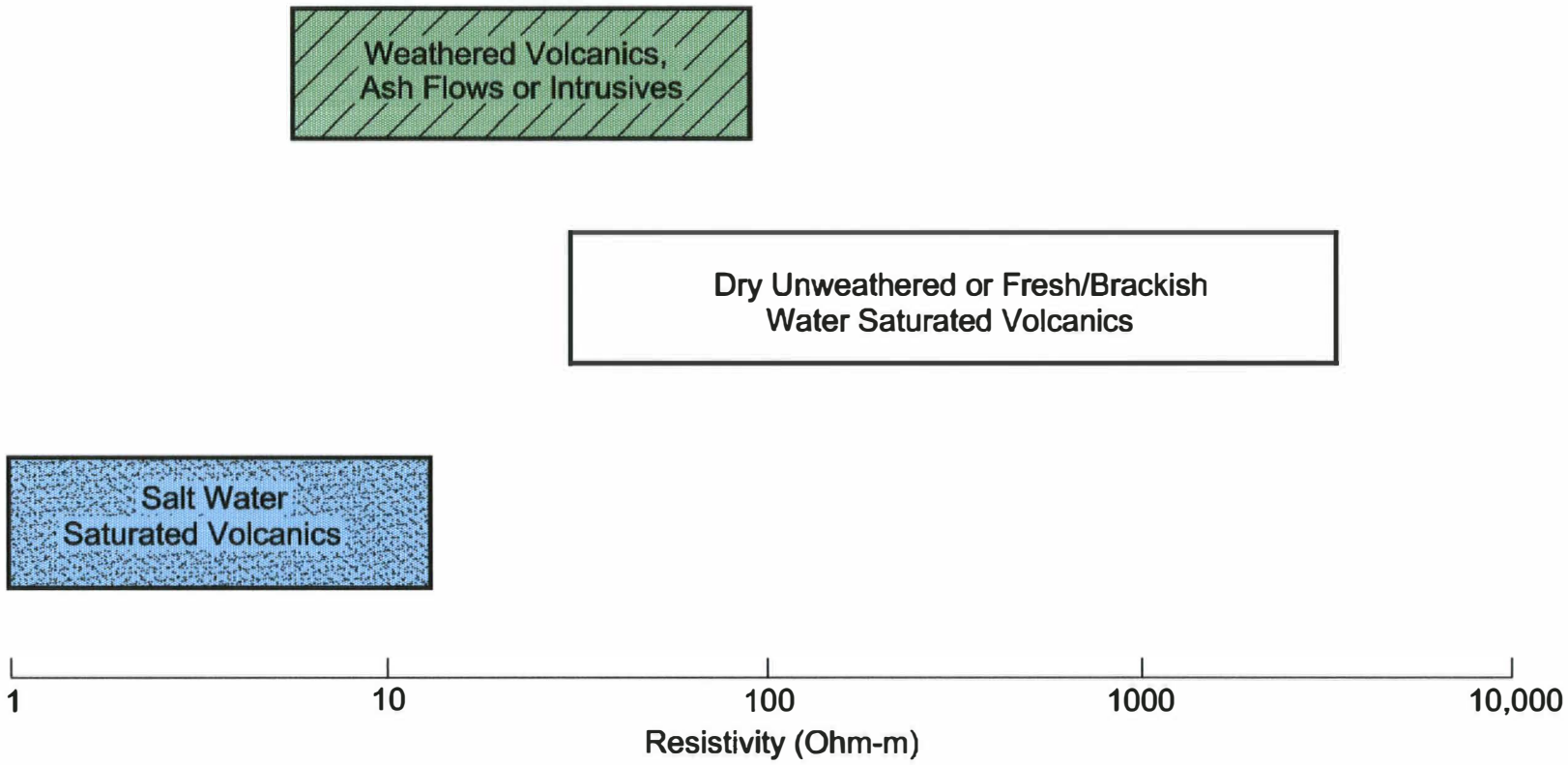
**TABLE 4-1**
**HYDROGEOLOGIC INFORMATION**
**DERIVED FROM TDEM SOUNDINGS**

| Sounding Number | Surface Elevation (Feet) | Estimated Thickness of Fresh-Brackish Water Lens (Feet) |
|---|---|---|
| 1 | 550 | 44 |
| 2 | 810 | 134.3 |
| 3 | 1080 | *? |
| 4 | 840 | *? |
| 5 | 1040 | *? |
| 6 | 700 | 215.3 |
| 7 | 940 | 186.5 |
| 8 | 1055 | 441.8 |

*Sounding Influenced by Lateral Discontinuity

The accuracy of determining the depth to the salt water interface from TDEM soundings is estimated to be ±5% of the total depth calculated in the sounding result (e.g., from the ground surface to salt water interface).

The results of the TDEM investigations have been further summarized in Figure 4-5. This map shows five soundings (1, 2, 6, 7, and 8) in which the ground water is interpreted in the basal mode (blue). Also shown, are Soundings 3, 4,and 5, (green) which are interpreted to be influenced by lateral discontinuities (i.e., dikes, rift zone). The boundary of an inferred geologic/hydrologic discontinuity is placed upslope from Soundings 3, 4, and 5, which appears to better define the boundary of the Northwest Rift Zone in these locations. Basal mode water lens thickness increases upslope on both sides of the Northwest Rift Zone, with an estimated thickness of 186 ft beneath Sounding 7 and a 442 ft lens thickness beneath Sounding 8.

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# Characteristic Resistivity Ranges

*Chalon International of Hawaii, Inc.*
*Hawi, Hawaii*

Project No. 9831 Figure: 4-1

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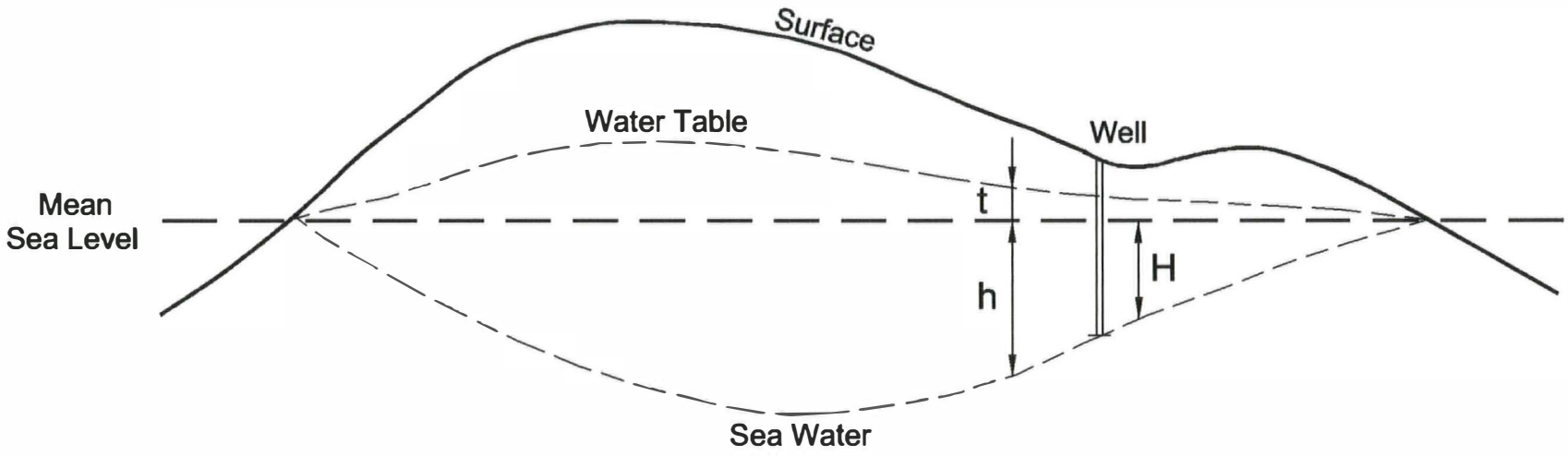


t = 1/40 (h)

*From: Herzberg*

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## Illustration of the Ghyben-Herzberg Principle

*Chalon International of Hawaii, Inc.*
*Hawi, Hawaii*

Project No. 9831 Figure: 4-2

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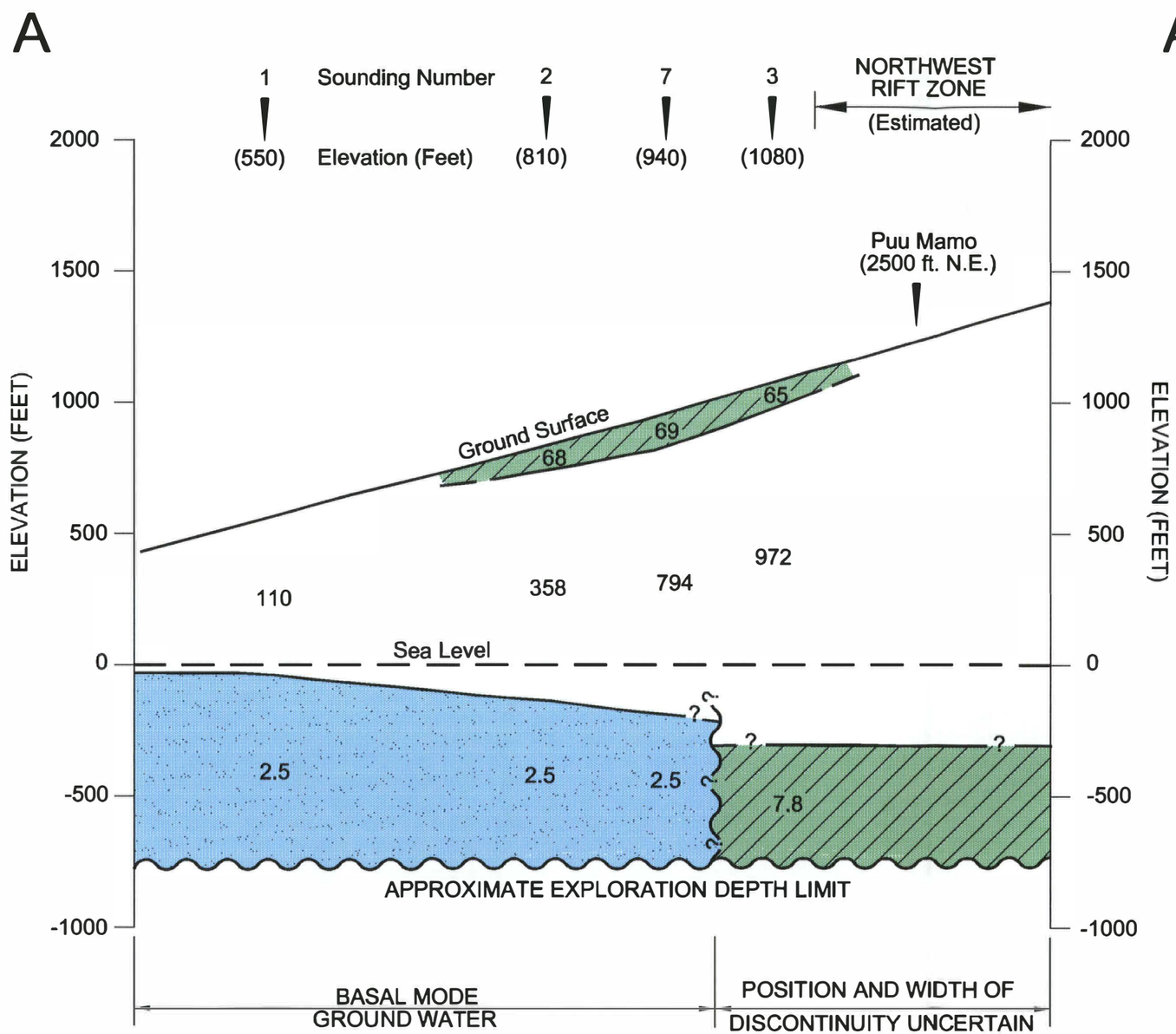


## Explanation

110 Resistivity in ohm-m

Weathered volcanics at surface or inferred structure (possible ash flows, or intrusives) at depth

Dry unweathered or fresh-brackish water saturated volcanics

Salt water saturated volcanics

Inferred geologic/hydrologic discontinuity

500 ft.

0 2000 ft.

Horizontal Scale Exaggeration 4:1

BLACKHAWK GEOMETRICS

# Geoelectric Cross Section A-A' North Kohala Site

*Chalon International of Hawaii, Inc.*
*Hawi, Hawaii*

Project No. 9831 Figure: 4-3

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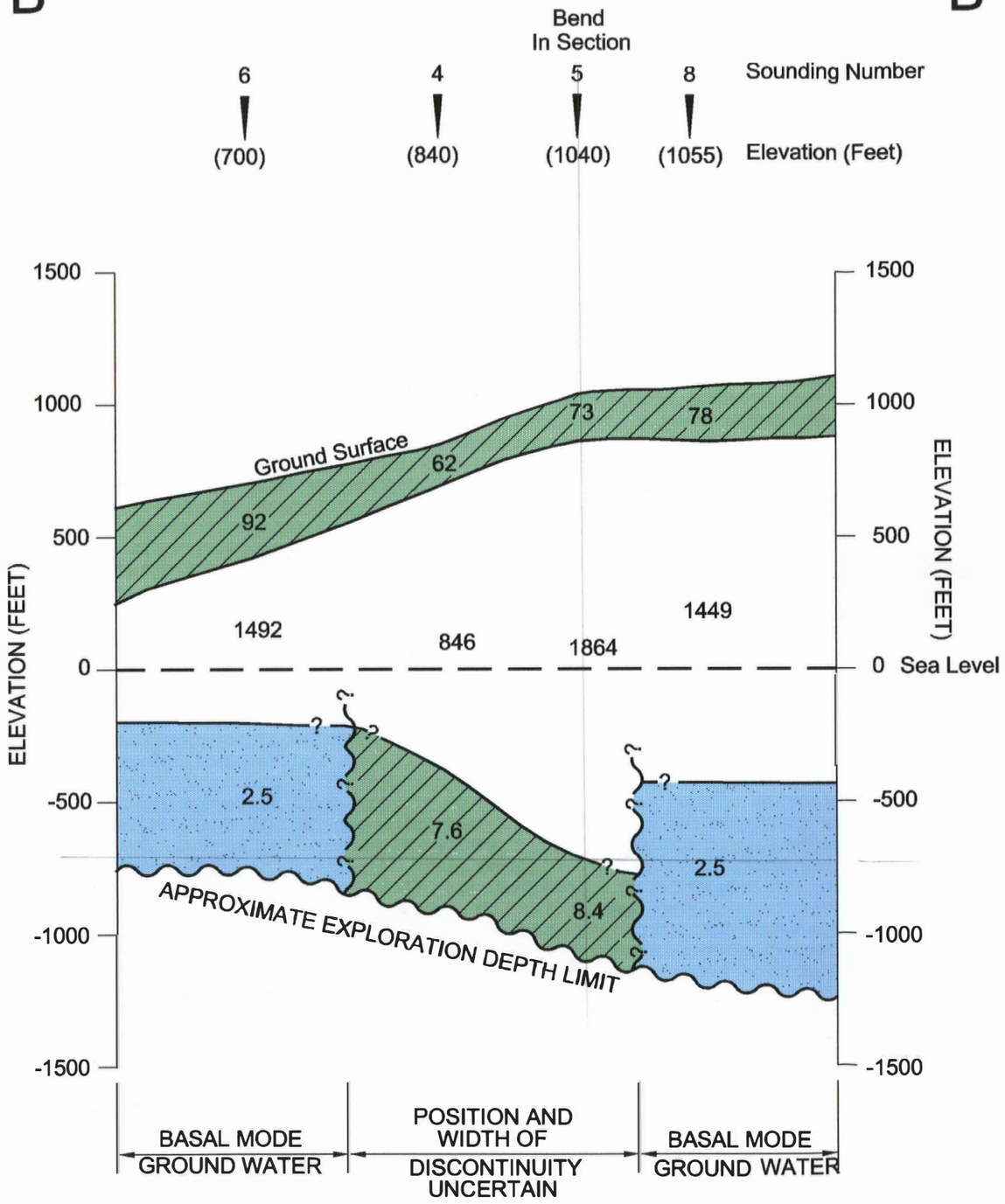


## Explanation

92 Resistivity in ohm-m

Weathered volcanics at surface or inferred structure (possible ash flows, or intrusives) at depth

Dry unweathered or fresh-brackish water saturated volcanics

Salt water saturated volcanics

Inferred geologic/hydrologic discontinuity

500 ft.

0 2000 ft.

Horizontal Scale Exaggeration 4:1

BLACKHAWK GEOMETRICS

# Geoelectric Cross Section B-B' North Kohala Site

*Chalon International of Hawaii, inc.*
*Hawi, Hawaii*

Project No. 9831 Figure: 4-4

\projects\9831cih\Xsecbb.dwg

Northwest Rift Zone
*(Estimated Boundary)*

Volcanic Cinder Cone
*(From Stearns and Macdonald, 1946)*

J(4.2) -210

H(7.0)

-43

-131

-182

-431

20°12'30"

155°52'30"

155°50'00"

KAHOLA HISTORICAL SITES STATE MONUMENT

Honolulu Landing (Site)

Puakea Pt

Holoholo Bay

Kehoni

Hikapoloa

Puu Ula

Puakea Ranch

Puakea Res

Powerline

Pipeline

Kahei

Hawi

Honomakau

Kehala Schools

Kamehameha Park

Water Tank

Tank

Cem

Rock Wall

Fort Mamo

Puu o Nale

Nunulu 2

Spring

KUKUIPAHU

KAPUNAPUNA

KAPAA 1-2

KAPAANUI

KOU

HAENA

AWALUA

HONOPUEHU

KAPAAU

HONOMAKAU

KAHEI

HOMESTEADS

Pipeline

Kumakua Gulch

Kapua Gulch

Hamauli Gulch

Ohanaulu Gulch

Waikaulapaia Gulch

Kapaapu Gulch

Hapakaoei Gulch

Pueo Gulch

Hanaula Gulch

1 2 3 4 5 6 7 8

## Explanation

- 1 — Sounding in which ground water is expected in basal mode
- Sounding influenced by lateral discontinuity (dikes, rift zone)
- -43 — Estimated elevation of top of salt water interface in feet
- Inferred geologic/hydrologic discontinuity (exact position uncertain)
- H(7.0) — Well, Water Level (In Feet)
- Hawaii — Survey Location

0 2000 4000 6000
Scale in Feet
Contour Interval 40 Feet

True North 10° Magnetic North

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# Summary Map North Kohala Site

*Chalon International of Hawaii, Inc.*
*Hawi, Hawaii*

Project No. 9831 Figure: 4-5

\projects\9831cih\Summap.dwg

# 5.0 CONCLUSIONS AND RECOMMENDATIONS

The results of the TDEM surveys at the North Kohala site near Hawi, Hawaii, indicate that beneath five soundings, a lens of basal mode fresh-brackish water occurs (see Figure 4-5). The thickest lens of potential fresh-brackish water resource is interpreted to occur beneath Sounding 8, and it is estimated to be 442 ft. In the vicinity of Soundings 3, 4, and 5, subsurface structures (i.e., dikes) that appear to be related to the Northwest Rift Zone are interpreted. The Northwest Rift Zone from Kohala Mountain intersects the survey area at about a N35°W bearing in line with Puu Ula and Puu Mamo. Near Soundings 3, 4, and 5, the potential for ground water exists, but it is expected to be controlled by geologic structures (e.g., rift zone, dikes), and ground water yield and quality in these areas may be highly variable. The ground water resources within areas controlled by geologic structures cannot be determined directly from the TDEM sounding data.

When comparing TDEM results from soundings taken at similar elevations on either side of the Northwest Rift Zone, it is evident that soundings on the east side of the rift zone show a thicker zone of potential fresh-brackish water resource than the west side.

Sounding 6, taken upslope from Well J (Underwood, M. R., 1995), showed good comparison of calculated head from TDEM data (5.25 ft) to the reported head of 4.2 ft.

To confirm the position of the inferred ground water damming structure, additional soundings on either side of the Northwest Rift Zone to better define the structure would be needed. Areas of potential high-level water were not located during this study. If this is an objective at the study site, additional TDEM data can be taken along the Northwest Rift Zone to confirm or deny this potential water resource.

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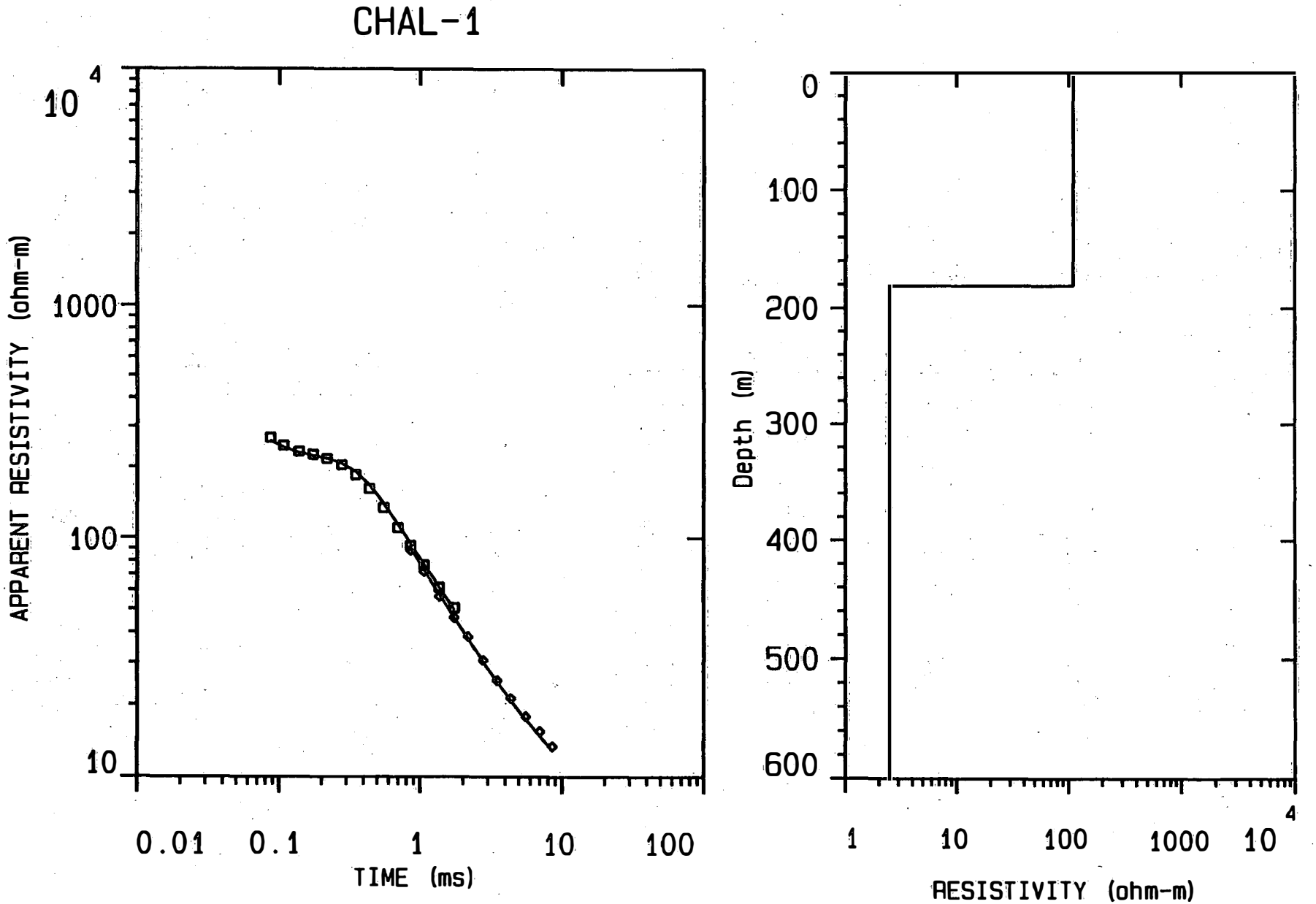
5. Wilt, M. J., 1991. Interpretation of time domain electromagnetic soundings near geologic contacts, Ph.D. Thesis, Lawrence Berkeley Laboratory, University of California Earth Sciences Division, pp. 185.


CHAL-1
APPARENT RESISTIVITY (ohm-m)
10 4
1000
100
10
0.01
0.1
1
10
100
TIME (ms)
Depth (m)
0
100
200
300
400
500
600
1
10
100
1000
10 4
RESISTIVITY (ohm-m)

DATA SET: CHAL-1

CLIENT: CHALON INTERNATIONAL DATE: 09-29-98
LOCATION: HAWI, HAWAII SOUNDING: 1
COUNTY: NORTH KOHALA ELEVATION: 168.00 m
PROJECT: NORTH KOHALA TDEM SURVEY EQUIPMENT: Geonics PROTEM
LOOP SIZE: 183.000 m by 183.000 m AZIMUTH:
COIL LOC: 0.000 m (X), 0.000 m (Y) TIME CONSTANT: NONE
SOUNDING COORDINATES: E: 1.0000 N: 1.0000 SLOPE: NONE

Central Loop Configuration
Geonics PROTEM System

FITTING ERROR: 3.685 PERCENT

| L # | RESISTIVITY (ohm-m) | THICKNESS (meters) | ELEVATION (meters) | (FT) | CONDUCTANCE (Siemens) |
|---|---|---|---|---|---|
| | | | 168.0 | 550.0 | |
| 1 | 110.2 | 181.1 | -13.12 | -43.0 | 1.64 |
| 2 | 2.50 * | | | | |

"*" INDICATES FIXED PARAMETER

CURRENT: 16.00 AMPS EM-37 COIL AREA: 100.00 sq m.
FREQUENCY: 30.00 Hz GAIN: 4 RAMP TIME: 110.00 muSEC

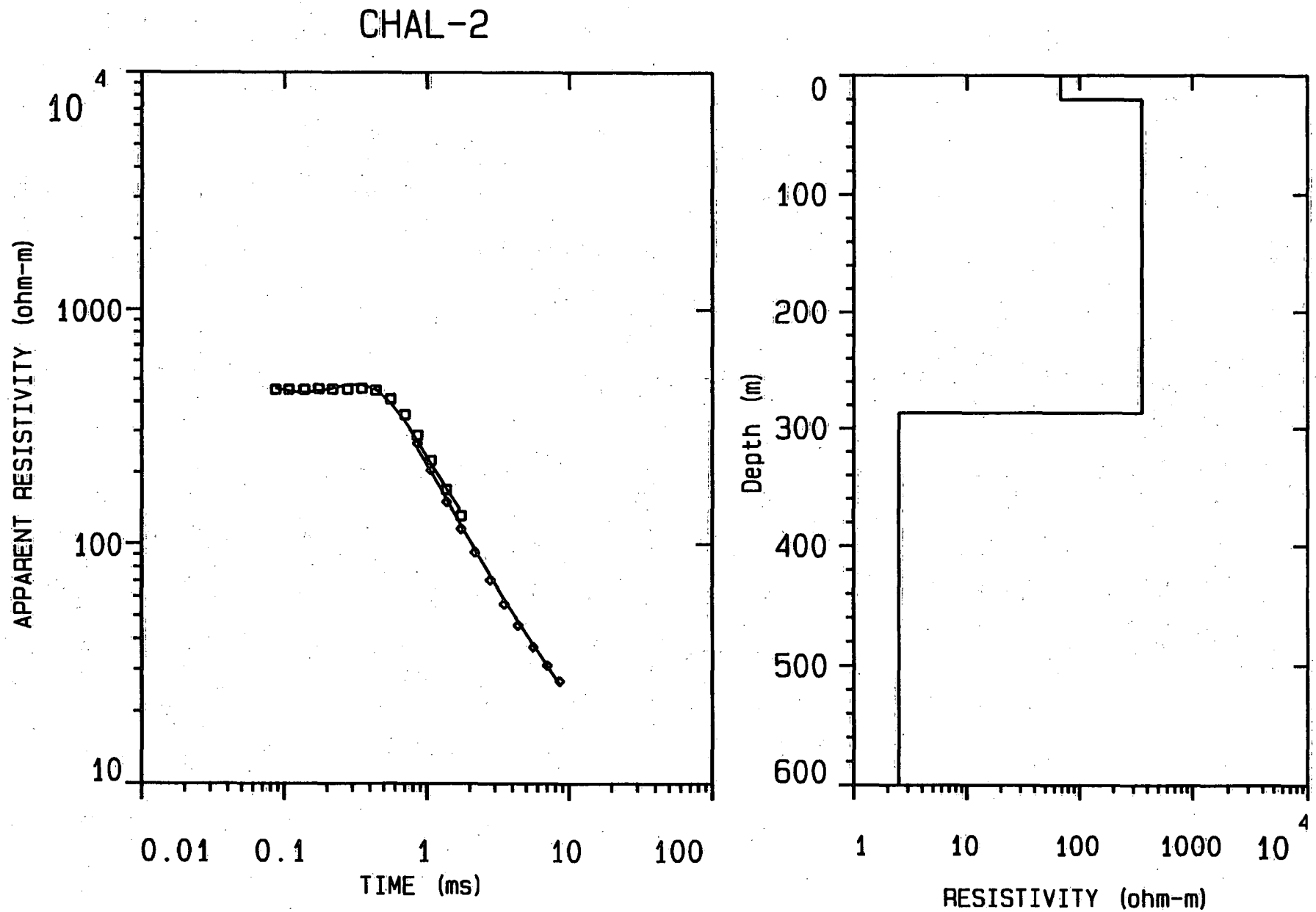
| No. | TIME (ms) | emf (nV/m sqrd) DATA | SYNTHETIC | DIFFERENCE (percent) |
|---|---|---|---|---|
| 1 | 0.0867 | 27618.0 | 28783.1 | -4.21 |
| 2 | 0.108 | 17887.4 | 18471.7 | -3.26 |
| 3 | 0.138 | 10601.8 | 10806.0 | -1.92 |
| 4 | 0.175 | 6140.5 | 6246.0 | -1.71 |
| 5 | 0.218 | 3768.2 | 3746.4 | 0.579 |
| 6 | 0.278 | 2254.6 | 2193.3 | 2.71 |
| 7 | 0.351 | 1459.3 | 1391.7 | 4.63 |
| 8 | 0.438 | 1025.9 | 973.7 | 5.09 |
| 9 | 0.558 | 746.7 | 704.6 | 5.63 |
| 10 | 0.702 | 560.5 | 535.9 | 4.38 |
| 11 | 0.858 | 441.6 | 429.9 | 2.65 |
| 12 | 1.06 | 341.6 | 338.4 | 0.947 |
| 13 | 1.37 | 252.2 | 254.4 | -0.866 |
| 14 | 1.74 | 186.8 | 192.0 | -2.79 |

CURRENT: 16.00 AMPS EM-37 COIL AREA: 100.00 sq m.
FREQUENCY: 3.00 Hz GAIN: 6 RAMP TIME: 110.00 muSEC

| No. | TIME (ms) | emf (nV/m sqrd) DATA | SYNTHETIC | DIFFERENCE (percent) |
|---|---|---|---|---|
| 15 | 0.857 | 476.1 | 458.7 | 3.66 |
| 16 | 1.06 | 376.7 | 365.6 | 2.93 |
| 17 | 1.37 | 288.6 | 280.3 | 2.86 |
| 18 | 1.74 | 214.8 | 216.5 | -0.787 |
| 19 | 2.17 | 162.9 | 168.4 | -3.40 |
| 20 | 2.77 | 124.0 | 126.5 | -2.01 |
| 21 | 3.50 | 92.52 | 94.52 | -2.17 |
| 22 | 4.37 | 68.82 | 70.88 | -2.98 |
| 23 | 5.56 | 48.88 | 50.97 | -4.27 |
| 24 | 6.98 | 34.18 | 36.77 | -7.55 |
| 25 | 8.56 | 25.51 | 27.05 | -6.03 |

PARAMETER RESOLUTION MATRIX:
"F" INDICATES FIXED PARAMETER

| | | | |
|---|---|---|---|
| P 1 | 0.99 | | |
| F 2 | 0.00 | 0.00 | |
| T 1 | 0.00 | 0.00 | 1.00 |
| | P 1 | F 2 | T 1 |


CHAL-2
APPARENT RESISTIVITY (ohm-m)
10 4
1000
100
10
0.01
0.1
1
10
100
TIME (ms)
Depth (m)
0
100
200
300
400
500
600
1
10
100
1000
10 4
RESISTIVITY (ohm-m)

DATA SET: CHAL-2

CLIENT: CHALON INTERNATIONAL DATE: 09-30-98
LOCATION: HAWI, HAWAII SOUNDING: 2
COUNTY: NORTH KOHALA ELEVATION: 247.00 m
PROJECT: NORTH KOHALA TDEM SURVEY EQUIPMENT: Geonics PROTEM
LOOP SIZE: 244.000 m by 244.000 m AZIMUTH:
COIL LOC: 0.000 m (X), 0.000 m (Y) TIME CONSTANT: NONE
SOUNDING COORDINATES: E: 2.0000 N: 1.0000 SLOPE: NONE

Central Loop Configuration
Geonics PROTEM System

FITTING ERROR: 5.344 PERCENT

| L # | RESISTIVITY (ohm-m) | THICKNESS (meters) | ELEVATION (meters) | (FT) | CONDUCTANCE (Siemens) |
|---|---|---|---|---|---|
| | | | 247.0 | 810.3 | |
| 1 | 67.71 | 20.23 | 226.7 | 743.7 | 0.298 |
| 2 | 358.0 | 266.6 | -39.85 | -130.7 | 0.744 |
| 3 | 2.50 * | | | | |

"*" INDICATES FIXED PARAMETER

CURRENT: 17.25 AMPS EM-37 COIL AREA: 100.00 sq m.
FREQUENCY: 30.00 Hz GAIN: 5 RAMP TIME: 150.00 muSEC

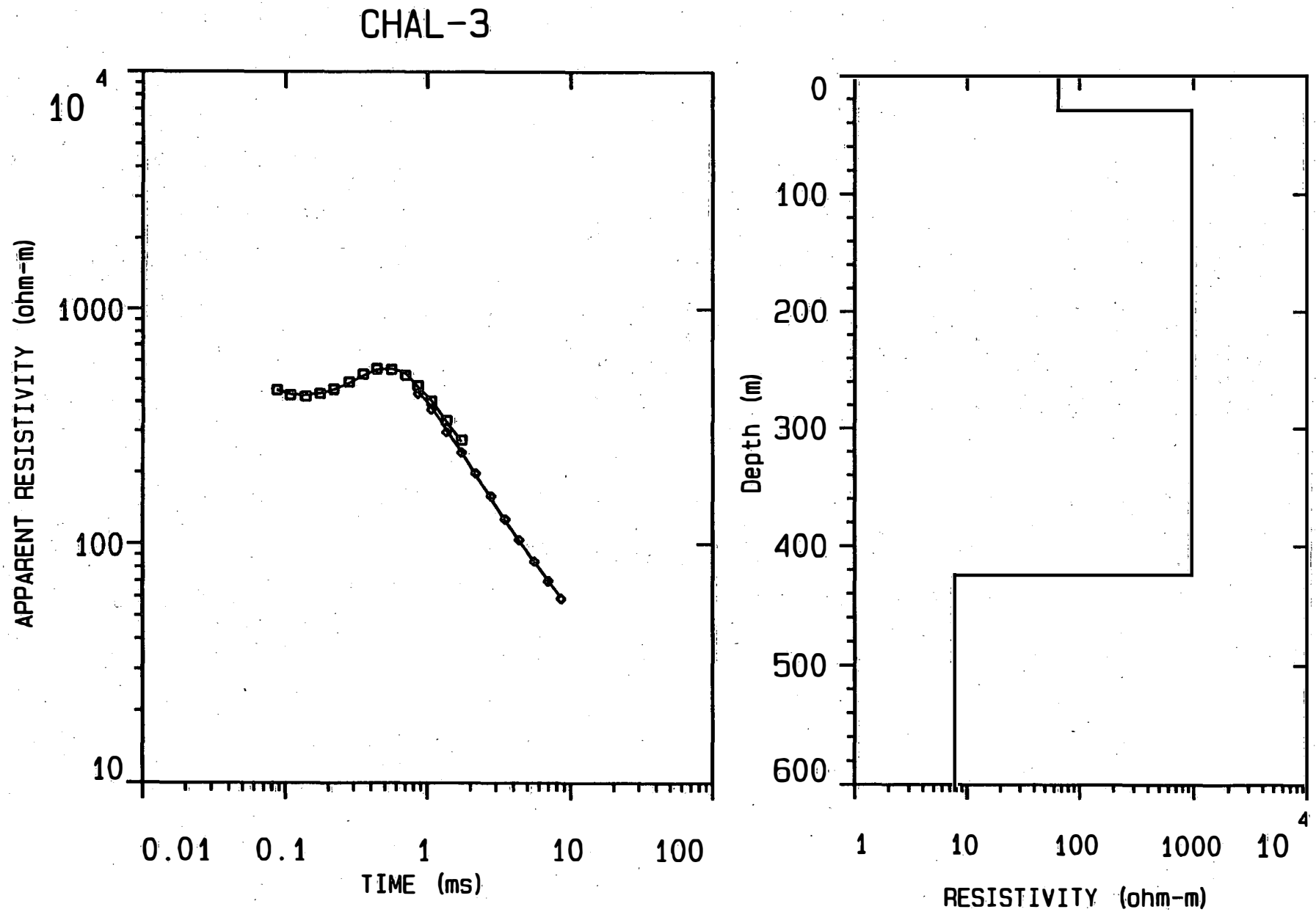
| No. | TIME (ms) | emf (nV/m sqrd) DATA | SYNTHETIC | DIFFERENCE (percent) |
|---|---|---|---|---|
| 1 | 0.0867 | 24368.9 | 23676.5 | 2.84 |
| 2 | 0.108 | 14051.2 | 14382.3 | -2.35 |
| 3 | 0.138 | 7605.8 | 7943.9 | -4.44 |
| 4 | 0.175 | 4152.6 | 4271.6 | -2.86 |
| 5 | 0.218 | 2410.3 | 2366.4 | 1.82 |
| 6 | 0.278 | 1307.5 | 1221.1 | 6.61 |
| 7 | 0.351 | 723.8 | 685.4 | 5.29 |
| 8 | 0.438 | 426.2 | 419.6 | 1.53 |
| 9 | 0.558 | 264.6 | 284.4 | -7.47 |
| 10 | 0.702 | 188.0 | 208.6 | -10.93 |
| 11 | 0.858 | 154.2 | 168.6 | -9.32 |
| 12 | 1.06 | 129.6 | 135.4 | -4.51 |
| 13 | 1.37 | 106.1 | 105.3 | 0.710 |
| 14 | 1.74 | 85.84 | 81.75 | 4.76 |

CURRENT: 17.25 AMPS EM-37 COIL AREA: 100.00 sq m.
FREQUENCY: 3.00 Hz GAIN: 7 RAMP TIME: 150.00 muSEC

| No. | TIME (ms) | emf (nV/m sqrd) DATA | SYNTHETIC | DIFFERENCE (percent) |
|---|---|---|---|---|
| 15 | 0.857 | 173.9 | 188.0 | -8.09 |
| 16 | 1.06 | 150.0 | 154.1 | -2.72 |
| 17 | 1.37 | 127.5 | 123.2 | 3.34 |
| 18 | 1.74 | 104.0 | 98.84 | 4.99 |
| 19 | 2.17 | 84.19 | 80.87 | 3.95 |
| 20 | 2.77 | 68.20 | 63.60 | 6.74 |
| 21 | 3.50 | 53.98 | 50.32 | 6.76 |
| 22 | 4.37 | 41.91 | 39.70 | 5.27 |
| 23 | 5.56 | 31.21 | 30.33 | 2.81 |
| 24 | 6.98 | 23.09 | 23.18 | -0.400 |
| 25 | 8.56 | 17.31 | 17.98 | -3.88 |

PARAMETER RESOLUTION MATRIX:
"F" INDICATES FIXED PARAMETER

| | P 1 | P 2 | F 3 | T 1 | T 2 |
|---|---|---|---|---|---|
| P 1 | 0.73 | | | | |
| P 2 | 0.13 | 0.70 | | | |
| F 3 | 0.00 | 0.00 | 0.00 | | |
| T 1 | -0.18 | -0.15 | 0.00 | 0.63 | |
| T 2 | 0.01 | 0.02 | 0.00 | 0.03 | 1.00 |


CHAL-3
APPARENT RESISTIVITY (ohm-m)
10 4
1000
100
10
0.01
0.1
1
10
100
TIME (ms)
Depth (m)
0
100
200
300
400
500
600
1
10
100
1000
10 4
RESISTIVITY (ohm-m)

DATA SET: CHAL-3

CLIENT: CHALON INTERNATIONAL
DATE: 09-30-98
LOCATION: HAWI, HAWAII
SOUNDING: 3
COUNTY: NORTH KOHALA
ELEVATION: 329.00 m
PROJECT: NORTH KOHALA TDEM SURVEY
EQUIPMENT: Geonics PROTEM
LOOP SIZE: 305.000 m by 305.000 m
AZIMUTH:
COIL LOC: 0.000 m (X), 0.000 m (Y)
TIME CONSTANT: NONE
SOUNDING COORDINATES: E: 3.0000 N: 1.0000
SLOPE: NONE

Central Loop Configuration
Geonics PROTEM System

FITTING ERROR: 2.122 PERCENT

| L # | RESISTIVITY (ohm-m) | THICKNESS (meters) | ELEVATION (meters) | (FT) | CONDUCTANCE (Siemens) |
|---|---|---|---|---|---|
| | | | 329.0 | 1080 | |
| 1 | 65.37 | 29.27 | 299.7 | 983.3 | 0.447 |
| 2 | 972.0 | 395.2 | -95.48 | -313.3 | 0.406 |
| 3 | 7.78 | | | | |

ALL PARAMETERS ARE FREE

CURRENT: 15.00 AMPS
EM-37
COIL AREA: 100.00 sq m.
FREQUENCY: 30.00 Hz
GAIN: 4
RAMP TIME: 160.00 muSEC

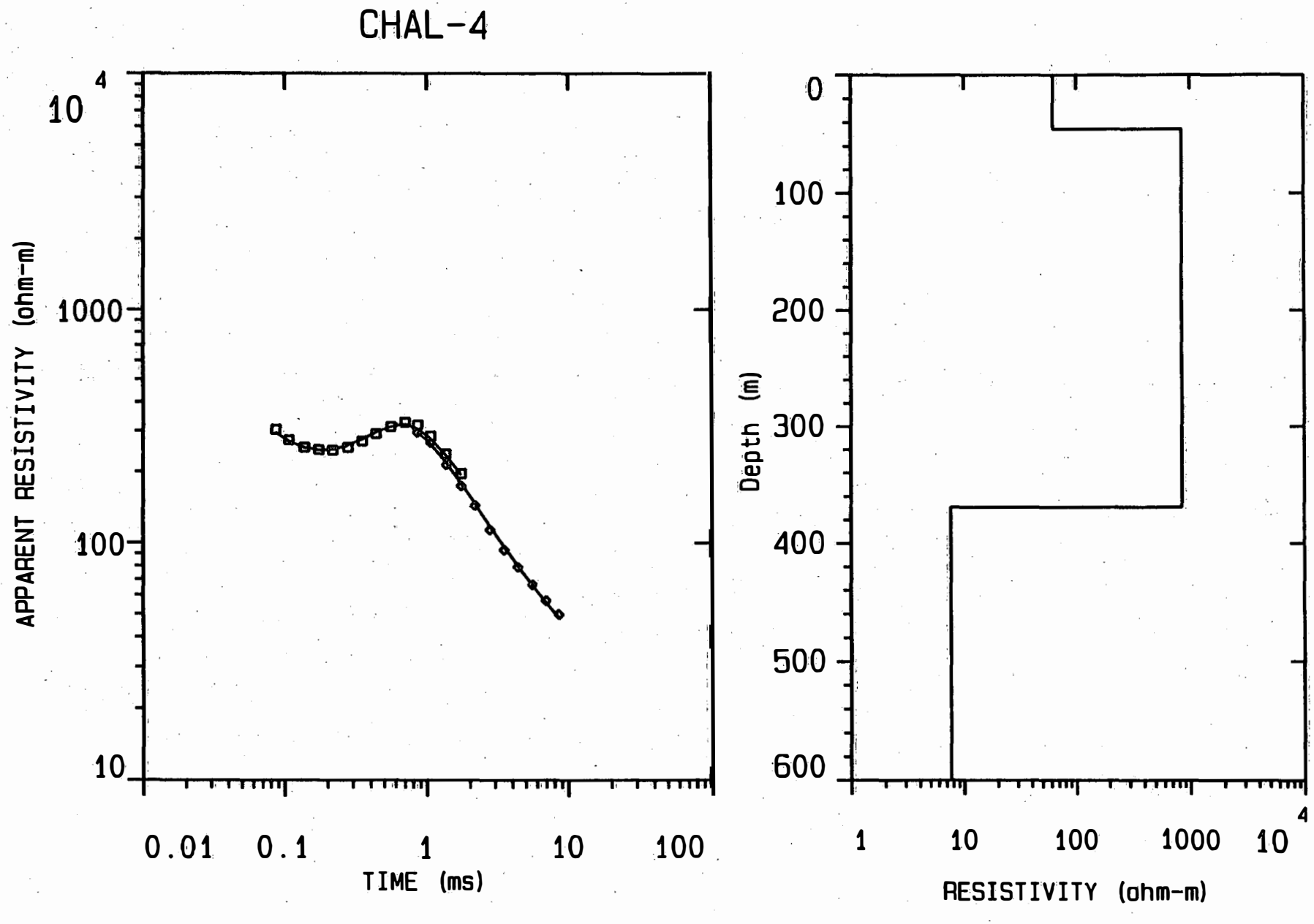
| No. | TIME (ms) | emf (nV/m sqrd) DATA | SYNTHETIC | DIFFERENCE (percent) |
|---|---|---|---|---|
| 1 | 0.0867 | 33235.8 | 33222.1 | 0.0412 |
| 2 | 0.108 | 20629.7 | 20387.4 | 1.17 |
| 3 | 0.138 | 11475.7 | 11224.5 | 2.18 |
| 4 | 0.175 | 6064.6 | 6060.6 | 0.0653 |
| 5 | 0.218 | 3281.5 | 3300.0 | -0.565 |
| 6 | 0.278 | 1603.8 | 1636.5 | -2.03 |
| 7 | 0.351 | 795.3 | 817.0 | -2.72 |
| 8 | 0.438 | 423.1 | 428.7 | -1.32 |
| 9 | 0.558 | 233.0 | 230.4 | 1.10 |
| 10 | 0.702 | 143.3 | 138.1 | 3.59 |
| 11 | 0.858 | 100.8 | 102.7 | -1.81 |
| 12 | 1.06 | 73.59 | 72.86 | 0.991 |
| 13 | 1.37 | 52.33 | 53.74 | -2.69 |
| 14 | 1.74 | 38.50 | 39.29 | -2.04 |

CURRENT: 15.00 AMPS EM-37 COIL AREA: 100.00 sq m.
FREQUENCY: 3.00 Hz GAIN: 7 RAMP TIME: 160.00 muSEC

| No. | TIME (ms) | emf (nV/m sqrd) DATA | SYNTHETIC | DIFFERENCE (percent) |
|---|---|---|---|---|
| 15 | 0.857 | 113.7 | 110.4 | 2.95 |
| 16 | 1.06 | 83.37 | 80.13 | 3.88 |
| 17 | 1.37 | 62.32 | 60.69 | 2.62 |
| 18 | 1.74 | 46.28 | 45.88 | 0.855 |
| 19 | 2.17 | 36.23 | 37.30 | -2.93 |
| 20 | 2.77 | 27.39 | 28.08 | -2.51 |
| 21 | 3.50 | 21.49 | 21.96 | -2.20 |
| 22 | 4.37 | 16.61 | 16.75 | -0.825 |
| 23 | 5.56 | 12.42 | 12.52 | -0.852 |
| 24 | 6.98 | 9.34 | 9.31 | 0.338 |
| 25 | 8.56 | 7.26 | 7.06 | 2.63 |

PARAMETER RESOLUTION MATRIX:
"F" INDICATES FIXED PARAMETER

| | P 1 | P 2 | P 3 | T 1 | T 2 |
|---|---|---|---|---|---|
| P 1 | 0.95 | | | | |
| P 2 | 0.05 | 0.41 | | | |
| P 3 | 0.01 | -0.12 | 0.76 | | |
| T 1 | -0.04 | -0.08 | -0.01 | 0.94 | |
| T 2 | 0.00 | 0.02 | 0.00 | 0.01 | 1.00 |


CHAL-4
APPARENT RESISTIVITY (ohm-m)
10 4
1000
100
10
0.01
0.1
1
10
100
TIME (ms)
Depth (m)
0
100
200
300
400
500
600
1
10
100
1000
10 4
RESISTIVITY (ohm-m)

DATA SET: CHAL-4

CLIENT: CHALON INTERNATIONAL DATE: 10-01-98
LOCATION: HAWI, HAWAII SOUNDING: 4
COUNTY: NORTH KOHALA ELEVATION: 256.00 m
PROJECT: NORTH KOHALA TDEM SURVEY EQUIPMENT: Geonics PROTEM
LOOP SIZE: 305.000 m by 305.000 m AZIMUTH:
COIL LOC: 0.000 m (X), 0.000 m (Y) TIME CONSTANT: NONE
SOUNDING COORDINATES: E: 4.0000 N: 2.0000 SLOPE: NONE

Central Loop Configuration
Geonics PROTEM System

FITTING ERROR: 3.112 PERCENT

| L # | RESISTIVITY (ohm-m) | THICKNESS (meters) | ELEVATION (meters) | (FT) | CONDUCTANCE (Siemens) |
|---|---|---|---|---|---|
| | | | 256.0 | 840 | |
| 1 | 62.09 | 45.53 | 210.4 | 690.2 | 0.733 |
| 2 | 845.8 | 323.7 | -113.3 | -371.7 | 0.382 |
| 3 | 7.61 | | | | |

ALL PARAMETERS ARE FREE

CURRENT: 15.00 AMPS EM-37 COIL AREA: 100.00 sq m.
FREQUENCY: 30.00 Hz GAIN: 4 RAMP TIME: 160.00 muSEC

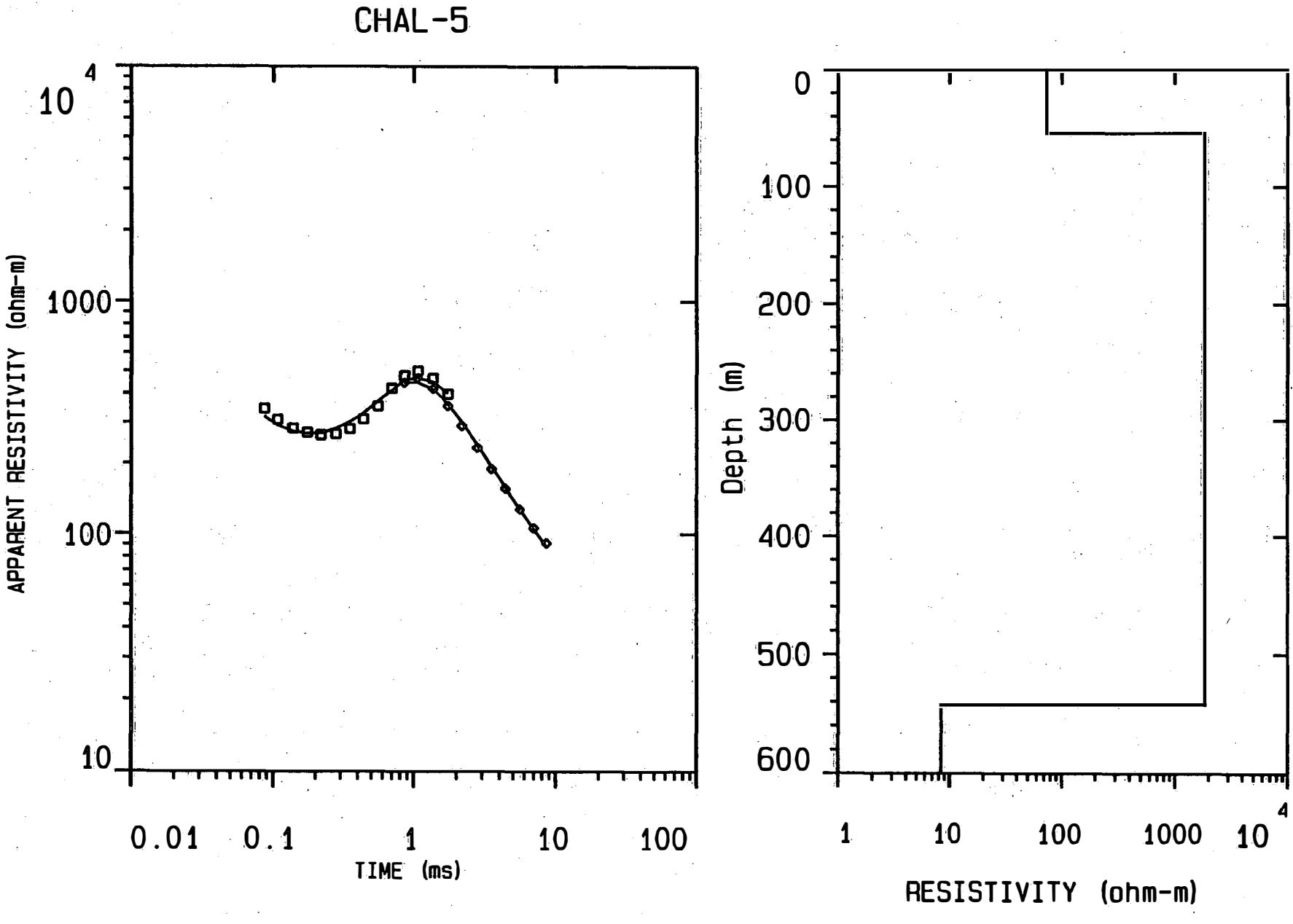
| No. | TIME (ms) | emf (nV/m sqrd) DATA | SYNTHETIC | DIFFERENCE (percent) |
|---|---|---|---|---|
| 1 | 0.0867 | 59822.5 | 62445.6 | -4.38 |
| 2 | 0.108 | 40320.1 | 41294.2 | -2.41 |
| 3 | 0.138 | 24382.7 | 24513.6 | -0.537 |
| 4 | 0.175 | 13977.2 | 14036.1 | -0.421 |
| 5 | 0.218 | 8132.4 | 7998.9 | 1.64 |
| 6 | 0.278 | 4251.1 | 4111.1 | 3.29 |
| 7 | 0.351 | 2159.6 | 2092.7 | 3.09 |
| 8 | 0.438 | 1109.0 | 1083.3 | 2.32 |
| 9 | 0.558 | 546.4 | 545.0 | 0.259 |
| 10 | 0.702 | 287.3 | 295.0 | -2.69 |
| 11 | 0.858 | 180.9 | 191.5 | -5.85 |
| 12 | 1.06 | 124.2 | 129.1 | -3.92 |
| 13 | 1.37 | 86.70 | 88.91 | -2.55 |
| 14 | 1.74 | 63.78 | 64.89 | -1.73 |

CURRENT: 15.00 AMPS EM-37 COIL AREA: 100.00 sq m.
FREQUENCY: 3.00 Hz GAIN: 7 RAMP TIME: 160.00 muSEC

| No. | TIME (ms) | emf (nV/m sqrd) DATA | SYNTHETIC | DIFFERENCE (percent) |
|---|---|---|---|---|
| 15 | 0.857 | 203.5 | 202.3 | 0.587 |
| 16 | 1.06 | 137.5 | 139.1 | -1.16 |
| 17 | 1.37 | 101.7 | 98.49 | 3.19 |
| 18 | 1.74 | 76.51 | 73.95 | 3.34 |
| 19 | 2.17 | 58.63 | 57.19 | 2.45 |
| 20 | 2.77 | 45.41 | 43.17 | 4.93 |
| 21 | 3.50 | 34.08 | 32.50 | 4.61 |
| 22 | 4.37 | 25.12 | 24.69 | 1.71 |
| 23 | 5.56 | 17.80 | 18.00 | -1.11 |
| 24 | 6.98 | 12.78 | 13.17 | -3.05 |
| 25 | 8.56 | 9.35 | 9.84 | -5.22 |

PARAMETER RESOLUTION MATRIX:
"F" INDICATES FIXED PARAMETER

| | | | | | |
|---|---|---|---|---|---|
| P 1 | 0.87 | | | | |
| P 2 | -0.06 | 0.13 | | | |
| P 3 | 0.04 | -0.06 | 0.79 | | |
| T 1 | -0.17 | -0.19 | 0.06 | 0.76 | |
| T 2 | 0.02 | 0.04 | 0.00 | 0.03 | 0.99 |
| | P 1 | P 2 | P 3 | T 1 | T 2 |


CHAL-5
APPARENT RESISTIVITY (ohm-m)
10 4
1000
100
10
0.01
0.1
1
10
100
TIME (ms)
Depth (m)
0
100
200
300
400
500
600
1
10
100
1000
10 4
RESISTIVITY (ohm-m)

DATA SET: CHAL-5

CLIENT: CHALON INTERNATIONAL
DATE: 10-01-98
LOCATION: HAWI, HAWAII
SOUNDING: 5
COUNTY: NORTH KOHALA
ELEVATION: 317.00 m
PROJECT: NORTH KOHALA TDEM SURVEY
EQUIPMENT: Geonics PROTEM
LOOP SIZE: 305.000 m by 305.000 m
AZIMUTH:
COIL LOC: 0.000 m (X), 0.000 m (Y)
TIME CONSTANT: NONE
SOUNDING COORDINATES: E: 5.0000 N: 2.0000
SLOPE: NONE

Central Loop Configuration
Geonics PROTEM System

FITTING ERROR: 6.118 PERCENT

| L # | RESISTIVITY (ohm-m) | THICKNESS (meters) | ELEVATION (meters) | (FT) | CONDUCTANCE (Siemens) |
|---|---|---|---|---|---|
| | | | 317.0 | 1040 | |
| 1 | 73.26 | 53.98 | 263.0 | 863 | 0.736 |
| 2 | 1864.1 | 488.4 | -225.3 | -739 | 0.262 |
| 3 | 8.39 | | | | |

ALL PARAMETERS ARE FREE

CURRENT: 15.00 AMPS
EM-37
COIL AREA: 100.00 sq m.
FREQUENCY: 30.00 Hz
GAIN: 4
RAMP TIME: 160.00 muSEC

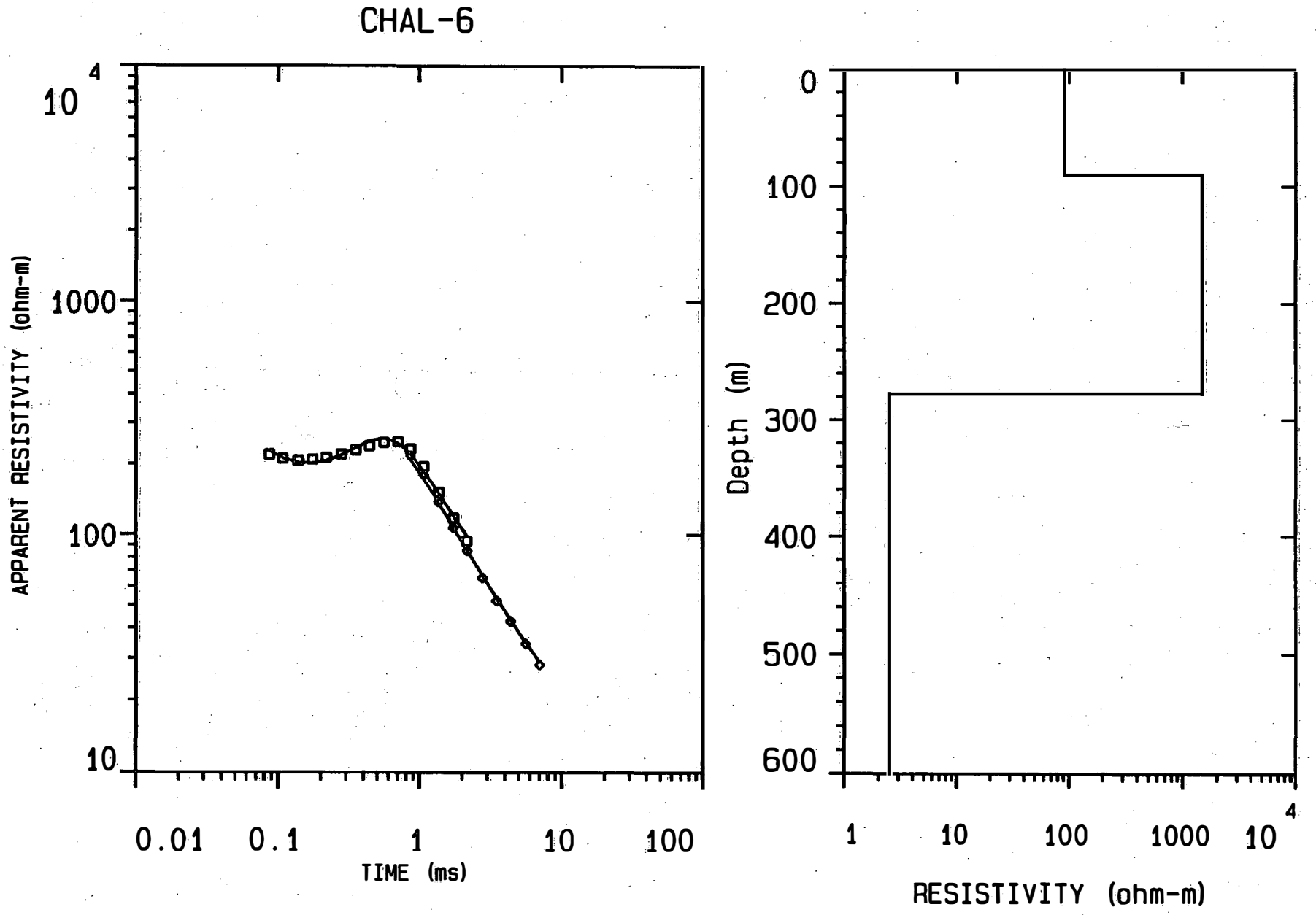
| No. | TIME (ms) | emf (nV/m sqrd) DATA | SYNTHETIC | DIFFERENCE (percent) |
|---|---|---|---|---|
| 1 | 0.0867 | 49613.5 | 55707.7 | -12.28 |
| 2 | 0.108 | 33567.5 | 36613.4 | -9.07 |
| 3 | 0.138 | 20672.0 | 21707.1 | -5.00 |
| 4 | 0.175 | 12183.8 | 12378.2 | -1.59 |
| 5 | 0.218 | 7306.5 | 7064.5 | 3.31 |
| 6 | 0.278 | 3923.3 | 3613.3 | 7.90 |
| 7 | 0.351 | 2017.4 | 1827.3 | 9.42 |
| 8 | 0.438 | 1007.3 | 920.0 | 8.66 |
| 9 | 0.558 | 451.6 | 419.0 | 7.22 |
| 10 | 0.702 | 195.5 | 201.4 | -3.04 |
| 11 | 0.858 | 98.27 | 104.8 | -6.72 |
| 12 | 1.06 | 53.20 | 59.07 | -11.03 |
| 13 | 1.37 | 31.69 | 33.42 | -5.44 |
| 14 | 1.74 | 22.01 | 21.77 | 1.09 |

CURRENT: 15.00 AMPS EM-37 COIL AREA: 100.00 sq m.
FREQUENCY: 3.00 Hz GAIN: 6 RAMP TIME: 160.00 muSEC

| No. | TIME (ms) | emf (nV/m sqrd) DATA | SYNTHETIC | DIFFERENCE (percent) |
|---|---|---|---|---|
| 15 | 0.857 | 109.3 | 109.4 | -0.0395 |
| 16 | 1.06 | 59.30 | 63.12 | -6.44 |
| 17 | 1.37 | 37.11 | 37.31 | -0.548 |
| 18 | 1.74 | 26.27 | 25.47 | 3.05 |
| 19 | 2.17 | 20.35 | 19.18 | 5.76 |
| 20 | 2.77 | 15.33 | 14.63 | 4.57 |
| 21 | 3.50 | 11.69 | 11.29 | 3.44 |
| 22 | 4.37 | 8.95 | 8.82 | 1.48 |
| 23 | 5.56 | 6.67 | 6.67 | -0.0290 |
| 24 | 6.98 | 4.98 | 5.07 | -1.69 |
| 25 | 8.56 | 3.75 | 3.90 | -4.12 |

PARAMETER RESOLUTION MATRIX:
"F" INDICATES FIXED PARAMETER

| | P 1 | P 2 | P 3 | T 1 | T 2 |
|---|---|---|---|---|---|
| P 1 | 0.92 | | | | |
| P 2 | -0.05 | 0.08 | | | |
| P 3 | 0.02 | -0.06 | 0.75 | | |
| T 1 | -0.09 | -0.14 | 0.03 | 0.88 | |
| T 2 | 0.01 | 0.02 | -0.01 | 0.01 | 1.00 |


CHAL-6
APPARENT RESISTIVITY (ohm-m)
10 4
1000
100
10
0.01
0.1
1
10
100
TIME (ms)
Depth (m)
0
100
200
300
400
500
600
1
10
100
1000
10 4
RESISTIVITY (ohm-m)

DATA SET: CHAL-6

CLIENT: CHALON INTERNATIONAL DATE: 10-02-98
LOCATION: HAWI, HAWAII SOUNDING: 6
COUNTY: NORTH KOHALA ELEVATION: 213.00 m
PROJECT: NORTH KOHALA TDEM SURVEY EQUIPMENT: Geonics PROTEM
LOOP SIZE: 213.000 m by 213.000 m AZIMUTH:
COIL LOC: 0.000 m (X), 0.000 m (Y) TIME CONSTANT: NONE
SOUNDING COORDINATES: E: 6.0000 N: 2.0000 SLOPE: NONE

Central Loop Configuration
Geonics PROTEM System

FITTING ERROR: 4.592 PERCENT

| L # | RESISTIVITY (ohm-m) | | THICKNESS (meters) | ELEVATION (meters) | (FT) | CONDUCTANCE (Siemens) |
|---|---|---|---|---|---|---|
| | | | | 213.0 | 700.0 | |
| 1 | 92.34 | | 89.48 | 123.5 | 405.2 | 0.969 |
| 2 | 1491.9 | | 187.4 | -63.90 | -209.6 | 0.125 |
| 3 | 2.50 | * | | | | |

"*" INDICATES FIXED PARAMETER

CURRENT: 14.50 AMPS EM-37 COIL AREA: 100.00 sq m.
FREQUENCY: 30.00 Hz GAIN: 4 RAMP TIME: 110.00 muSEC

| No. | TIME (ms) | emf (nV/m sqrd) DATA | SYNTHETIC | DIFFERENCE (percent) |
|---|---|---|---|---|
| 1 | 0.0867 | 45803.8 | 43456.3 | 5.12 |
| 2 | 0.108 | 28087.3 | 27903.2 | 0.655 |
| 3 | 0.138 | 15677.1 | 16120.9 | -2.83 |
| 4 | 0.175 | 8471.9 | 8994.5 | -6.16 |
| 5 | 0.218 | 4772.9 | 5003.7 | -4.83 |
| 6 | 0.278 | 2481.0 | 2498.3 | -0.696 |
| 7 | 0.351 | 1300.0 | 1256.0 | 3.38 |
| 8 | 0.438 | 702.0 | 651.5 | 7.19 |
| 9 | 0.558 | 366.7 | 342.6 | 6.59 |
| 10 | 0.702 | 203.6 | 207.5 | -1.93 |
| 11 | 0.858 | 136.4 | 146.6 | -7.47 |
| 12 | 1.06 | 102.7 | 110.4 | -7.50 |
| 13 | 1.37 | 80.49 | 81.81 | -1.63 |
| 14 | 1.74 | 64.92 | 63.00 | 2.95 |

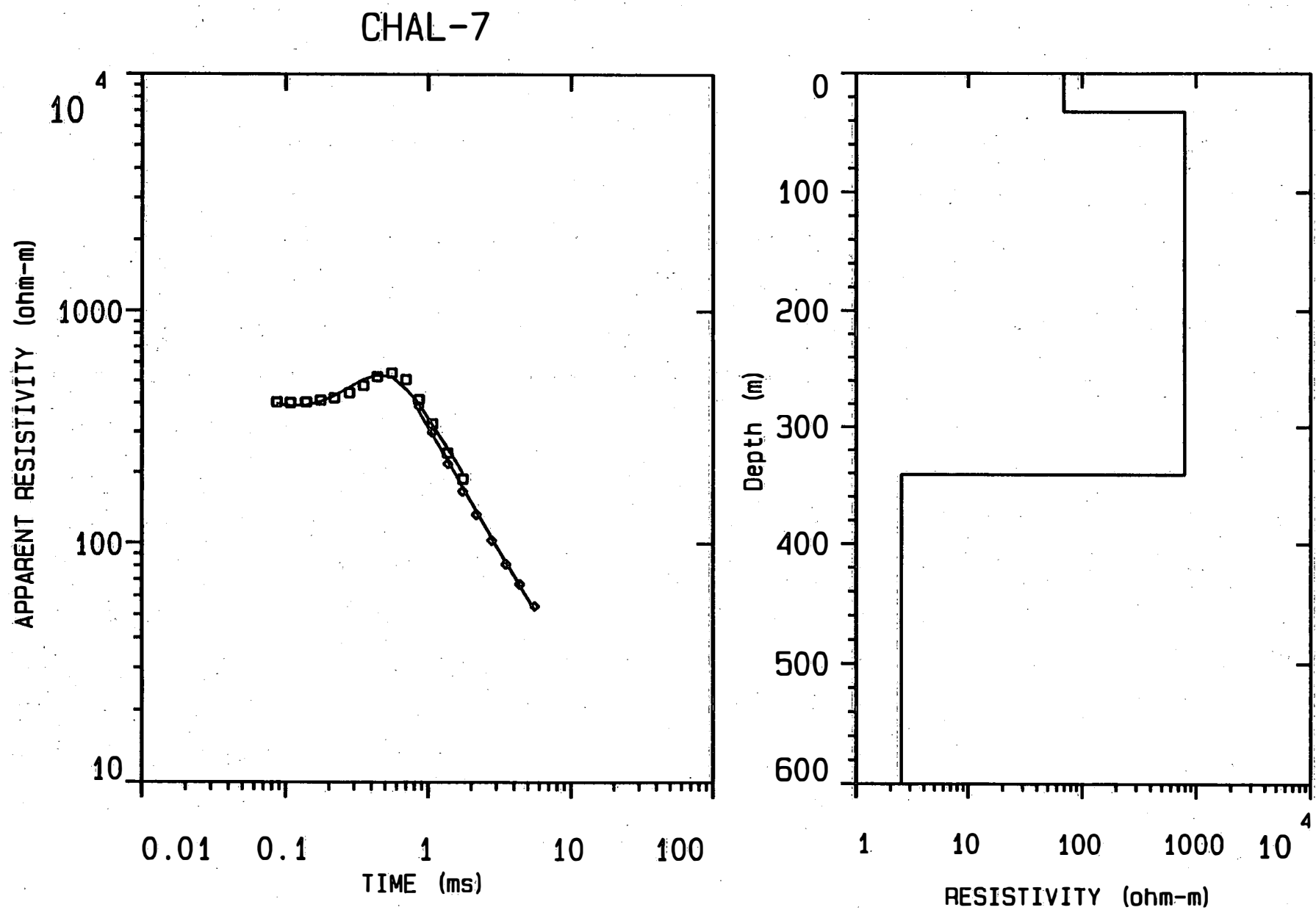
| No. | TIME (ms) | emf (nV/m sqrd) DATA | SYNTHETIC | DIFFERENCE (percent) |
|---|---|---|---|---|
| 15 | 2.17 | 52.39 | 48.77 | 6.89 |

CURRENT: 14.50 AMPS EM-37 COIL AREA: 100.00 sq m.
FREQUENCY: 3.00 Hz GAIN: 6 RAMP TIME: 110.00 muSEC

| No. | TIME (ms) | emf (nV/m sqrd) DATA | SYNTHETIC | DIFFERENCE (percent) |
|---|---|---|---|---|
| 16 | 0.857 | 151.0 | 160.5 | -6.26 |
| 17 | 1.06 | 116.2 | 123.7 | -6.41 |
| 18 | 1.37 | 93.08 | 94.52 | -1.54 |
| 19 | 1.74 | 75.03 | 75.09 | -0.0894 |
| 20 | 2.17 | 60.33 | 60.20 | 0.213 |
| 21 | 2.77 | 48.99 | 47.24 | 3.58 |
| 22 | 3.50 | 38.25 | 36.84 | 3.69 |
| 23 | 4.37 | 29.48 | 28.94 | 1.82 |
| 24 | 5.56 | 22.38 | 21.91 | 2.09 |
| 25 | 6.98 | 17.20 | 16.63 | 3.30 |

PARAMETER RESOLUTION MATRIX:
"F" INDICATES FIXED PARAMETER

| | | | | | |
|---|---|---|---|---|---|
| P 1 | 0.96 | | | | |
| P 2 | 0.00 | 0.00 | | | |
| F 3 | 0.00 | 0.00 | 0.00 | | |
| T 1 | -0.06 | -0.04 | 0.00 | 0.90 | |
| T 2 | 0.03 | 0.02 | 0.00 | 0.04 | 0.98 |
| | P 1 | P 2 | F 3 | T 1 | T 2 |


CHAL-7
APPARENT RESISTIVITY (ohm-m)
10^4
1000
100
10
0.01
0.1
1
10
100
TIME (ms)
Depth (m)
0
100
200
300
400
500
600
1
10
100
1000
10^4
RESISTIVITY (ohm-m)

DATA SET: CHAL-7

CLIENT: CHALON INTERNATIONAL DATE: 10-02-98
LOCATION: HAWI, HAWAII SOUNDING: 7
COUNTY: NORTH KOHALA ELEVATION: 286.00 m
PROJECT: NORTH KOHALA TDEM SURVEY EQUIPMENT: Geonics PROTEM
LOOP SIZE: 244.000 m by 244.000 m AZIMUTH:
COIL LOC: 0.000 m (X), 0.000 m (Y) TIME CONSTANT: NONE
SOUNDING COORDINATES: E: 7.0000 N: 1.0000 SLOPE: NONE

Central Loop Configuration
Geonics PROTEM System

FITTING ERROR: 6.098 PERCENT

| L # | RESISTIVITY (ohm-m) | THICKNESS (meters) | ELEVATION (meters) | (FT) | CONDUCTANCE (Siemens) |
|---|---|---|---|---|---|
| | | | 286.0 | 940.0 | |
| 1 | 69.25 | 32.34 | 253.6 | 832.0 | 0.466 |
| 2 | 794.2 | 309.0 | -55.35 | -181.6 | 0.389 |
| 3 | 2.50 * | | | | |

"*" INDICATES FIXED PARAMETER

CURRENT: 17.50 AMPS EM-37 COIL AREA: 100.00 sq m.
FREQUENCY: 30.00 Hz GAIN: 5 RAMP TIME: 155.00 muSEC

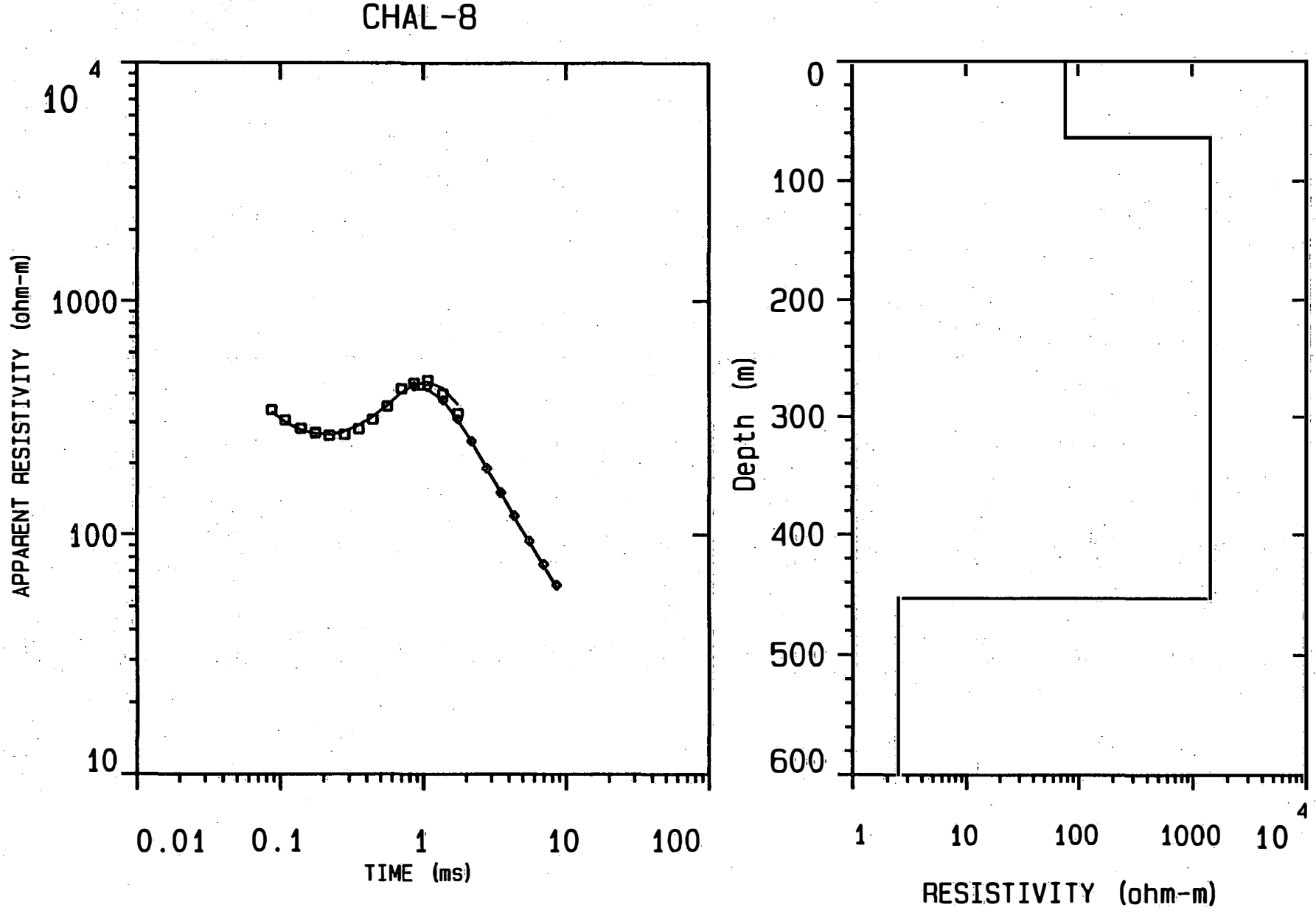
| No. | TIME (ms) | emf (nV/m sqrd) DATA | SYNTHETIC | DIFFERENCE (percent) |
|---|---|---|---|---|
| 1 | 0.0867 | 29137.9 | 29804.8 | -2.28 |
| 2 | 0.108 | 16977.4 | 17767.6 | -4.65 |
| 3 | 0.138 | 9128.1 | 9553.8 | -4.66 |
| 4 | 0.175 | 4876.5 | 4987.7 | -2.28 |
| 5 | 0.218 | 2730.4 | 2646.0 | 3.09 |
| 6 | 0.278 | 1378.6 | 1268.8 | 7.96 |
| 7 | 0.351 | 686.1 | 631.1 | 8.02 |
| 8 | 0.438 | 346.5 | 338.1 | 2.41 |
| 9 | 0.558 | 179.4 | 189.8 | -5.74 |
| 10 | 0.702 | 111.2 | 128.7 | -15.74 |
| 11 | 0.858 | 90.67 | 96.29 | -6.19 |
| 12 | 1.06 | 75.57 | 76.88 | -1.73 |
| 13 | 1.37 | 62.81 | 58.97 | 6.11 |
| 14 | 1.74 | 50.98 | 46.68 | 8.43 |

CURRENT: 17.50 AMPS EM-37 COIL AREA: 100.00 sq m.
FREQUENCY: 3.00 Hz GAIN: 7 RAMP TIME: 155.00 muSEC

| No. | TIME (ms) | emf (nV/m sqrd) DATA | SYNTHETIC | DIFFERENCE (percent) |
|---|---|---|---|---|
| 15 | 0.857 | 100.7 | 108.9 | -8.14 |
| 16 | 1.06 | 86.52 | 89.08 | -2.96 |
| 17 | 1.37 | 74.22 | 70.70 | 4.74 |
| 18 | 1.74 | 61.16 | 57.88 | 5.35 |
| 19 | 2.17 | 49.55 | 47.28 | 4.59 |
| 20 | 2.77 | 39.36 | 38.02 | 3.40 |
| 21 | 3.50 | 31.09 | 30.34 | 2.42 |
| 22 | 4.37 | 23.86 | 24.38 | -2.20 |
| 23 | 5.56 | 17.95 | 18.95 | -5.54 |

PARAMETER RESOLUTION MATRIX:
"F" INDICATES FIXED PARAMETER

| | P 1 | P 2 | F 3 | T 1 | T 2 |
|---|---|---|---|---|---|
| P 1 | 0.90 | | | | |
| P 2 | 0.02 | 0.29 | | | |
| F 3 | 0.00 | 0.00 | 0.00 | | |
| T 1 | -0.10 | -0.14 | 0.00 | 0.84 | |
| T 2 | 0.01 | 0.02 | 0.00 | 0.02 | 1.00 |


CHAL-8
APPARENT RESISTIVITY (ohm-m)
10 4
1000
100
10
0.01
0.1
1
10
100
TIME (ms)
Depth (m)
0
100
200
300
400
500
600
1
10
100
1000
10 4
RESISTIVITY (ohm-m)

DATA SET: CHAL-8

CLIENT: CHALON INTERNATIONAL DATE: 10-10-98
LOCATION: HAWI, HAWAII SOUNDING: 8
COUNTY: NORTH KOHALA ELEVATION: 322.00 m
PROJECT: NORTH KOHALA TDEM SURVEY EQUIPMENT: Geonics PROTEM
LOOP SIZE: 305.000 m by 305.000 m AZIMUTH:
COIL LOC: 0.000 m (X), 0.000 m (Y) TIME CONSTANT: NONE
SOUNDING COORDINATES: E: 8.0000 N: 100.0000 SLOPE: NONE

Central Loop Configuration
Geonics PROTEM System

FITTING ERROR: 4.289 PERCENT

| L # | RESISTIVITY (ohm-m) | THICKNESS (meters) | ELEVATION (meters) | (FT) | CONDUCTANCE (Siemens) |
|---|---|---|---|---|---|
| | | | 322.0 | 1055.0 | |
| 1 | 78.23 | 63.83 | 258.1 | 846.8 | 0.815 |
| 2 | 1448.9 | 389.4 | -131.3 | -430.8 | 0.268 |
| 3 | 2.50 * | | | | |

"*" INDICATES FIXED PARAMETER

CURRENT: 15.00 AMPS EM-37 COIL AREA: 100.00 sq m.
FREQUENCY: 30.00 Hz GAIN: 3 RAMP TIME: 187.00 muSEC

| No. | TIME (ms) | emf (nV/m sqrd) DATA | SYNTHETIC | DIFFERENCE (percent) |
|---|---|---|---|---|
| 1 | 0.0867 | 50266.1 | 51870.3 | -3.19 |
| 2 | 0.108 | 33908.2 | 34929.5 | -3.01 |
| 3 | 0.138 | 20854.0 | 21235.6 | -1.82 |
| 4 | 0.175 | 12288.8 | 12445.8 | -1.27 |
| 5 | 0.218 | 7356.0 | 7238.1 | 1.60 |
| 6 | 0.278 | 3946.7 | 3776.7 | 4.30 |
| 7 | 0.351 | 2029.7 | 1924.2 | 5.19 |
| 8 | 0.438 | 1012.4 | 969.9 | 4.19 |
| 9 | 0.558 | 453.4 | 447.0 | 1.40 |
| 10 | 0.702 | 196.7 | 207.6 | -5.54 |
| 11 | 0.858 | 109.1 | 112.5 | -3.09 |
| 12 | 1.06 | 61.18 | 62.35 | -1.91 |
| 13 | 1.37 | 39.82 | 36.75 | 7.71 |
| 14 | 1.74 | 29.27 | 25.66 | 12.31 |

CURRENT: 15.00 AMPS EM-37 COIL AREA: 100.00 sq m.
FREQUENCY: 3.00 Hz GAIN: 7 RAMP TIME: 187.00 muSEC

| No. | TIME (ms) | emf (nV/m sqrd) DATA | SYNTHETIC | DIFFERENCE (percent) |
|---|---|---|---|---|
| 15 | 0.857 | 114.7 | 120.4 | -4.94 |
| 16 | 1.06 | 67.06 | 69.72 | -3.96 |
| 17 | 1.37 | 43.67 | 43.87 | -0.460 |
| 18 | 1.74 | 31.88 | 32.49 | -1.92 |
| 19 | 2.17 | 25.52 | 25.69 | -0.649 |
| 20 | 2.77 | 20.76 | 20.87 | -0.503 |
| 21 | 3.50 | 16.53 | 16.62 | -0.564 |
| 22 | 4.37 | 13.38 | 13.70 | -2.41 |
| 23 | 5.56 | 10.59 | 10.80 | -2.06 |
| 24 | 6.98 | 8.37 | 8.62 | -2.96 |
| 25 | 8.56 | 6.79 | 6.95 | -2.37 |

PARAMETER RESOLUTION MATRIX:
"F" INDICATES FIXED PARAMETER

| | P 1 | P 2 | F 3 | T 1 | T 2 |
|---|---|---|---|---|---|
| P 1 | 0.93 | | | | |
| P 2 | -0.04 | 0.06 | | | |
| F 3 | 0.00 | 0.00 | 0.00 | | |
| T 1 | -0.09 | -0.13 | 0.00 | 0.87 | |
| T 2 | 0.01 | 0.03 | 0.00 | 0.02 | 0.99 |